GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY, MALAYSIA
PERLIS-KEDAH-PULAU PINANG
REGIONAL WATER RESOURCES STUDY
PART 1

VOL. 1
MAIN REPORT

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JAPAN INTERNATIONAL COOPERATION AGENCY

NATIONAL WATER RESOURCES STUDY, MALAYSIA
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REGIONAL WATER RESOURCES STUDY
PART 1

LIST OF VOLUMES

PREFACE

It is with great pleasure that I present this report entitled National Water Resources Study, Malaysia, Perlis-Kedah-Pulau Pinang Regional Water Resources Study Part 1 to the Government of Malaysia.

This report embodies the result of a multidisciplinary survey which was carried out from December 1982 to February 1984 by the Japanese survey team commissioned by the Japan International Cooperation Agency following the request of the Government of Malaysia.

The study team, headed by Mr. Ichiro Kuno, had a series of close discussions with the officials concerned of the Government of Malaysia and conducted a wide scope of field survey and data analyses.

I sincerely hope that this report will be useful as a basic reference for development of the Project.

I am particularly pleased to express my appreciation to the officials concerned of the Government of Malaysia for their close cooperation extended to the Japanese team.

February 1984

Keisuke Arita
President
Japan International
Cooperation Agency

JAPAN INTERNATIONAL COOPERATION AGENCY

NATIONAL WATER RESOURCES STUDY, MALAYSIA
PERLIS-KEDAH-PULAU PINANG
REGIONAL WATER RESOURCES STUDY

February, 1984

Mr. Keisuke Arita
President
Japan International
Cooperation Agency
Tokyo

Dear Sir,

LETTER OF TRANSMITTAL

We are pleased to submit to you the Final Report of the National Water Resources Study, Malaysia, Perlis-Kedah-Pulau Pinang Regional Water Resources Study, Part 1, for the consideration by the Government of Malaysia in implementing water resources development and management in the specified Region, in line with nation's socio-economic development objective.

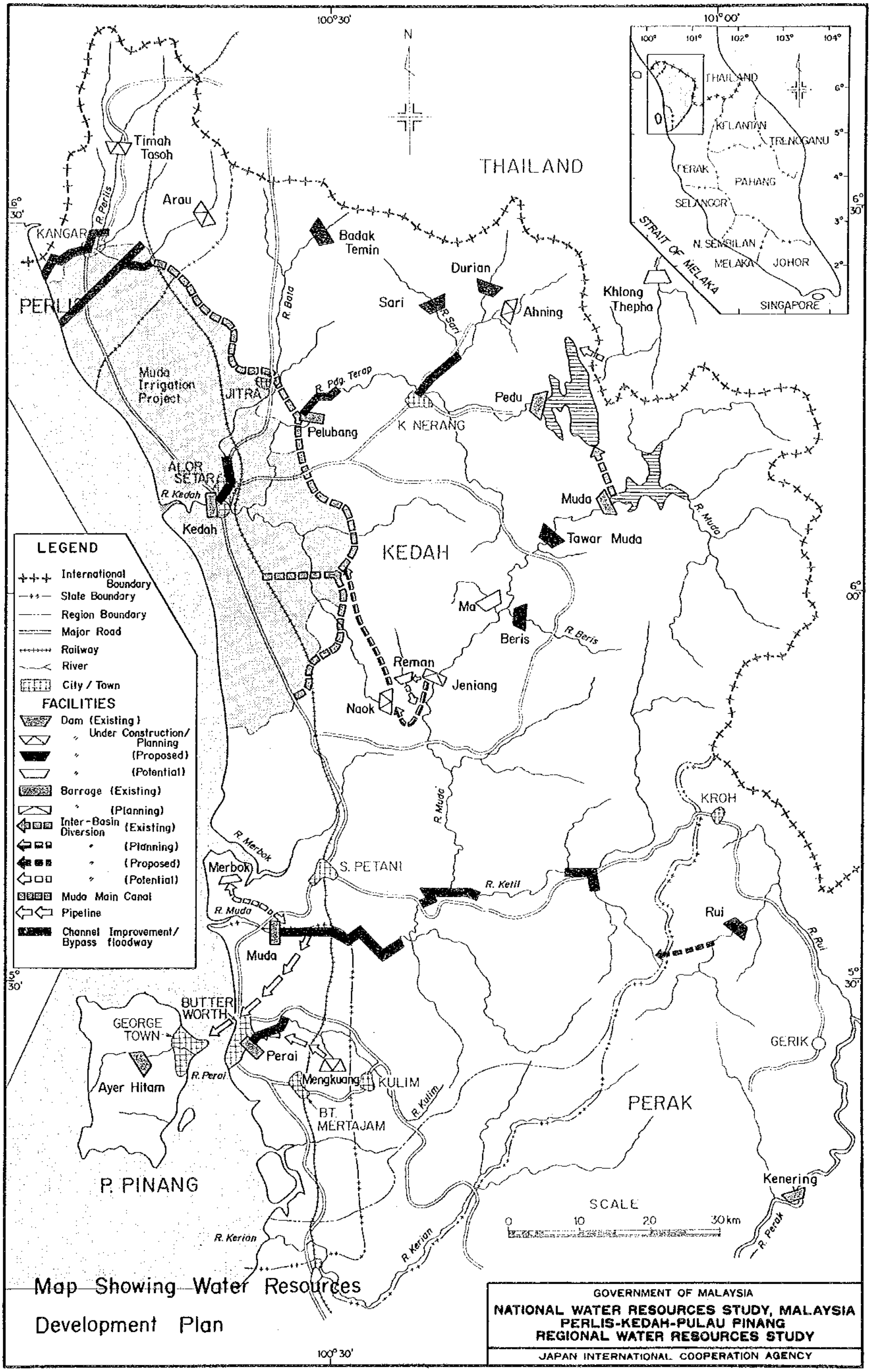
The rivers in the Perlis-Kedah-Pulau Pinang Region have formed an integrated water resources system, in which persisting water stress can not be alleviated unless water is reasonably and equitably distributed among the users, backed by a multipurpose water source development.

The submitted Report contains a recommended regional water resources master plan including a water demand and supply balance plan, flood mitigation plan, water pollution abatement plan, and legal and institutional arrangement.

All members of the Study Team wish to express grateful acknowledgement to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Construction and Embassy to Malaysia as well as officials and individuals of Malaysia for their assistance extended to the Study Team. The Study Team sincerely hopes that the study results would contribute to the water resources development of Malaysia in particular and to her socio-economic development and well-being in general.

Yours sincerely,

Ichiro Kuno
Team Leader



Map Showing Water Resources Development Plan

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY, MALAYSIA
PERLIS-KEDAH-PULAU PINANG
REGIONAL WATER RESOURCES STUDY
JAPAN INTERNATIONAL COOPERATION AGENCY

SUMMARY

1. STUDY OBJECTIVE

The National Water Resources Study, Malaysia (NWRS), 1979 - 1982, prepared the Master Action Plan containing recommendations on actions to be taken by the Federal and State Governments for water resources development and management, with a view that water resources are essential to attain national socio-economic goal, which is authorized in the Malaysia Five Years Development Plan, and that an integrated approach should be taken in water resources development and management, especially in the regions where water stress takes place.

The Perlis-Kedah-Pulau Pinang Region (the Region) is one of major water stress regions. It is a group of the Perlis, Kedah, Merbok, Muda and Perai river basins, where desired water demand and supply balance cannot be attained unless they are integrated into a few number of systems. The region roughly corresponds to the States of Perlis, Kedah and Pulau Pinang but does not include Pulau Langkawi and Kerian river basin, which can form separate water resources systems.

The objective of the Perlis-Kedah-Pulau Pinang Regional Water Resources Study (the Study) is to formulate an integrated water resources development and management plan for the Region to the extent that the decision making on the implementation of water resources development projects by the Federal and State Governments is made possible.

The presented Final Report for Part 1 contains a regional water resources master plan including recommended water demand and supply balance plan, flood mitigation plan, water pollution abatement plan and legal and institutional arrangement.

2. THE PERLIS-KEDAH-PULAU PINANG REGION

Average annual rainfall on the Region of 10,325 km^2 is 23,340 x 10^6 m^3, out of which 9,290 x 10^6 m^3 is surface runoff and the rest is evapotranspiration and groundwater recharge. Groundwater potential is poor except for a part of the State of Perlis. Exploitable groundwater is estimated to be 91 x 10^6 m^3.

Population in the States of Perlis, Kedah and Pulau Pinang was 2.3 x 10^6 in 1980 and gross regional product (GRP) in the same year was M$3.6 x 10^9 at 1970 constant price, according to the Fourth Malaysia Plan (4MP). Per capita GRP was M$1,070 in Perlis and Kedah and M$2,290 in Pulau Pinang. Economic structure is agricultural in Perlis and Kedah, growing tree crops for export and producing rice of more than half the national production, but it is industrial in Pulau Pinang, manufacturing output being next to the Kelang valley's.

The public water supply system is well developed, especially in urban areas. Population served by the public water supply systems in 1982 is 70% in Perlis, 68% in Kedah and 87% in Pulau Pinang. Domestic and industrial water demand including those supplied by public and private water supply system in 1982 is estimated to be 10 x 10^6 m^3/y for Perlis, 56 x 10^6 m^3/y for Kedah and 111 x 10^6 m^3/y for Pulau Pinang.

Paddy production in the Region in 1981/82 year was 964,000 tons, which was 3.5 times the Region's consumption. The Muda irrigation project commands 95,800 ha. The area of positive minor irrigation schemes is 3,700 ha in Perlis, 7,200 ha in Kedah and 15,100 ha in Pulau Pinang. Irrigation water demand in 1982 is estimated to be 1,621 x 10^6 m^3/y for the MADA area, 34 x 10^6 m^3/y for Perlis, 137 x 10^6 m^3/y for Kedah and 328 x 10^6 m^3/y for Pulau Pinang.

Runoff in the catchment area of the Muda dam of 984 km^2, or 23% of the Muda river basin is conveyed to the Pedu dam of 1,050 x 10^6 m^3 in active storage capacity. It is regulated and supplied to the Muda irrigation project through the Kedah river. The Ayer Hitam dam in the Pinang island serves for public water supply. The Kedah and Muda barrages are tidal barrages. The Perai barrage was constructed in order to protect Butterworth by retaining flood upstream the town.

The canal system of the Muda irrigation project takes water not only from the Kedah river but from some other rivers and also supplies raw water for domestic and industrial water supply in Kangar. Some minor irrigation schemes in the Perai river system take water from both the Muda and Perai rivers. Major sources for water supply system in Pulau Pinang including the Pinang island are the Muda and Perai rivers.

Natural runoff is generally low between January and August, and it sometimes lowers even in the remaining period of the year. Only a part of runoff can be utilized. It is estimated that natural runoff can just meet the present water demand in the Perlis river system. The present water demand in the Muda river system is 1,670 x 10^6 m^3, which is almost equal to natural runoff in a dry year in the Kedah river basin including the catchment area of the Muda dam. Even with a large regulating capacity of the Pedu and Muda dams, water deficit occurs every year. In fact, the period of two crop system usually exceeds over one year due to insufficient water and, as a result, the off season cropping is cancelled once in 6 years. The Muda river carries more than 1/3 of water in the Region. There is no water deficit in the Muda-Perai river system, except in a dry year which occurs once in several years, owing largely to the Muda barrage.

Rivers often inundate because of small channel capacity but flood damage is not an annual event. In a sense of long average, the annual flood damage is estimated to be M$9 x 10^6 and population affected to be 25,000 under the condition in 1982. Problem areas are Kangar, Kuala Nerang, Kuala Ketil, Butterworth, Georgetown and some rural areas.

Most rivers in the Region are clean to mildly polluted in terms of biochemical oxygen demand (BOD), but tributaries of the Merbok river and main stream of Julu river are highly polluted. The major pollutant sources are towns, rubber factories, palm oil mills, sugar mills and animal husbandry, while those located near the sea coast do not pollute river water, discharge effluent directly into the sea.

3. FUTURE WATER DEMAND

Population in the Region will be 2.5 x 10^6 in 1990, according to 4MP. It is estimated to be 3.1 x 10^6 in 2000, assuming that population growth rate in whole Malaysia will be 2% between the two years.

Two different cases are assumed in projecting gross domestic product (GDP): Growth rate of GDP is assumed to be 7.6% between 1980 and 1985, 8.4% between 1985 and 1990 and 7.5% between 1990 and 2000 for High Growth Case, and 6% between 1980 and 1985, 5% between 1985 and 1990 and 4% between 1990 and 2000 for Low Growth Case. Thus, GRP in 2000 in the Region is estimated to be M$15.9 x 10^9 for High Growth Case and M$8.7 x 10^9 for Low Growth Case.

The target service factor of public water supply system is preliminarily assumed to be 100% for High Growth Case and 97% for Low Growth Case. Domestic and industrial water demand in 2000 is estimated to be 39 x 10^6 m^3/y for Perlis, 248 x 10^6 m^3/y for Kedah and 422 x 10^6 m^3/y for Pulau Pinang in High Growth Case, and 18 x 10^6 m^3/y for Perlis, 113 x 10^6 m^3/y for Kedah and 293 x 10^6 m^3/y for Pulau Pinang in Low Growth Case.

The existing irrigation area will be partly converted for other land use but development of minor irrigation schemes will be continued. The irrigation area in 2000 is estimated to be 93,000 ha for the MADA area, 5,100 ha for Perlis, 19,700 ha for Kedah and 14,700 ha for Pulau Pinang. Corresponding irrigation water demand is estimated to be 1,485 x 10^6 m^3/y for the MADA area, 98 x 10^6 m^3/y for Perlis, 375 x 10^6 m^3/y for Kedah and 288 x 10^6 m^3/y for Pulau Pinang.

In view that instream water use is quite limited, the requirement for river maintenance flow is estimated from the viewpoint of water pollution abatement. It is estimated to be 1.5 m^3/s for High Growth Case and 0.4 m^3/s for Low Growth Case downstream of Kangar in the Perlis river and 6.2 m^3/s for High Growth Case and 2.3 m^3/s for Low Growth Case below Alor Setar in the Kedah river.

4. WATER DEMAND AND SUPPLY BALANCE PLAN

Water deficit will develop considerably, with increase in water demand. It is estimated that water deficit in the main stream in 2000 under the hydrological condition in a dry year, will be 29 x 10^6 m^3 in the Perlis river system, 463 x 10^6 m^3 in the Kedah river system and 164 x 10^6 m^3 in the Muda-Perai river system in High Growth Case, and it is 29 x 10^6 m^3 in the Perlis river system, 398 x 10^6 m^3 in the Kedah river system and 107 x 10^6 m^3 in the Muda-Perai river system in Low Growth Case.

In order to remove water deficit, some source development projects are under construction or committed for implementation. The Timah-Tasoh dam is envisaged for irrigation and flood mitigation in the Perlis river. If this dam is implemented, all water deficit up to 2000 in the Perlis river system can be avoided. The Arau dam for irrigation and flood mitigation will enable the development of minor irrigation schemes in the upper Arau river basin. The Ahning dam is constructed in the Kedah river system in order to develop raw water for Alor Setar and to generate hydropower. The Mengkuang dam under construction in the Perai river for domestic and industrial water supply can meet the water deficit in the Muda-Perai river system for the time being.

A large impact is expected from the Jeniang system, which is also committed for implementation. If the Jeniang system is implemented, surplus water is taken from the middle stretch of the Muda river and it is diverted to a southern half of the MADA area. Thus the Pedu dam can supply more water in other areas in the Kedah river system. The impact of the Jeniang system can be largely increased, if the Reman dam, presently pending, is implemented.

Water deficit can largely be reduced if all the above-mentioned source development projects are operational, but there will still remain a substantial water deficit. In Part 1 of the Study, 6 additional dam projects are studied at a pre-feasibility level. They are the Badak-Temin, Sari and Durian dams in the Kedah river system, the Tawar-Muda and Beris dams in the Muda river system and the Rui dam in the Perak river system. Among them, the Rui dam cannot be implemented in the near future due to uncertainty in mineral potential in its proposed reservoir area.

The remaining water deficit is so large that it cannot be totally avoided even if all the proposed dams are implemented. Moreover, the investment costs of some proposed dams seem to be high compared with the expected output. A study based on the economic optimization criteria assuming a discount rate of 8% as the opportinity cost of capital definitly shows that the Beris dam should be implemented in addition to the Jeniang system. The Tawar-Muda dam is another proposed dam which can be economically justified.

The Beris and Tawar-Muda dams are located upstream of the intake of the Jeniang system and, therefore, their water output can be compatibly utilized in the Muda-Perai river system and the Kedah river system. It is proposed that all water output from the Jeniang system and a part of water output from the Beris and Tawar-Muda dam should be utilized to meet water deficit in the Kedah river system, except for that caused by the minor irrigation development in tributaries. A part of water output from the Beris dam should be used to supply water deficit caused by the minor irrigation development in tributaries in both the Kedah and Muda-Perai river system, and the remaining water output from the Beris and Tawar-Muda dams should meet all the remaining water deficit in the Muda-Perai river basin.

The value of economic internal rate of return is estimated to be 12.2% in High Growth Case and 12.9% in Low Growth Case for the Jeniang system, 14.4% in High Growth Case and 13.5% in Low Growth Case for the Beris dam, and 11.5% in High Growth Case and 9.0% in Low Growth Case for the Tawar-Muda dam.

The proposed Beris dam is a concrete gravity dam of 42 m in maximum height and 145 m in crest length. It creates a reservoir of 101 x 10^6 m^3 in active storage capacity. The present land use in the proposed reservoir area of 15.4 km^2 is 774 ha of smallholders' rubber farms, 591 ha of forest and 175 ha of other lands. Houses included are 152 in number. The estimated investment cost comprises the construction cost of M$45.2 x 10^6 and land acquisition cost of M$29 x 10^6 at 1982 constant price.

The proposed Tawar-Muda dam consists of a main dam in the Muda river and a secondary dam in the Tawar river. The main dam is a rockfill dam of 34 m in maximum height and 338 m in crest length. The secondary dam is a rockfill dam of 31 m in maximum height and 1,040 m in crest length. The active storage capacity is 54 x 10^6 m^3. The present land use in the proposed reservoir area of 12.2 km^2 is 612 ha of rubber farms of RISDA and FELCRA, 540 ha of forest and 68 ha of other lands. Houses included are 33 in number. The estimated investment cost comprises the construction cost of M$103.8 x 10^6 and land acquisition cost of M$10.8 x 10^6 at 1982 constant price.

The public development expenditure for the water demand and supply balance in the whole Region is disbursed between 4MP and 7MP, including the construction costs for the public water supply systems, irrigation facilities, Jeniang system, Beris dam and Tawar-Muda dam, as well as the on-going Timah-Tasoh, Arau, Ahning and Mengkuang dams.

The total public development expenditure of M$3,836 x 10^6 in High Growth Case consists of M$1,176 x 10^6 for irrigation, M$2,654 x 10^6 for domestic and industrial water supply and M$6 x 10^6 for river maintenance flow, and that of M$2,669 x 10^6 in Low Growth Case comprises M$1,249 x 10^6 for irrigation and M$1,484 x 10^6 for domestic and industrial water supply. The large difference in the expenditure between High and Low Growth Cases is mainly attributable to the difference in the construction cost of public water supply system. The construction cost of the Jeniang system, Beris dam and Tawar-Muda dam is M$263 x 10^6 in total, of which the ratio to the total public expenditure is 7% in High Growth Case and 10% in Low Growth Case.

Estimated allocation of public development expenditure is M$1,313 x 10^6 to Perlis and Kedah, M$1,571 x 10^6 to Pulau Pinang and M$952 x 10^6 to MADA in High Growth Case, and M$713 x 10^6 to Perlis and Kedah, M$934 x 10^6 to Pulau Pinang and M$1,022 x 10^6 to MADA in Low Growth Case.

The development expenditure in private sector is estimated to be M$2,464 x 10^6 for High Growth Case and M$883 x 10^6 for Low Growth Case. This large amount is required for the construction of private water supply system including distribution systems in industrial estates and some intakes and conveyance systems.

All the water deficit cannot be met, even the Beris and Tawar-Muda dams are implemented. There are potential source development projects which are promissing to meet the remaining water deficit, though they are not assumed for the immediate implementation because of uncertainty. A study, assuming that all or some of the Reman, Khlong Thepha, Merbok and Rui projects can be implemented, shows that they are mostly quite attractive to balance the regional water demand supply and their cost of water may be even lower than that expected from the Tawar-Muda dam. The Reman is especially so, and all water deficit cannot be met unless the Reman is implemented.

It is aboveall recommended that the Beris dam be implemented. In view that a large water deficit will still remain, the Tawar-Muda dam should also be implemented, if no potential dam can be implemented. It is further recommended that the possibility of implementation of the potential dam should be seriously scrutinized through consultation and coordination among the authorities concerned.

5. FLOOD MITIGATION PLAN

The structural measures for flood mitigation are increase in the discharge capacity in the river by channel improvement, diversion of flood through a bypass floodway and retention of flood in a reservoir or retarding basin. Flood mitigation plans are recommended for the Perlis, Kedah, Muda, Perai and Pinang rivers.

The major problem area is Kangar in the Perlis river basin. The recommended plan for the river consists of the construction of the Timah-Tasoh and Arau dams, channel improvement of river stretches of 23 km in total length and bypass floodways of 22 km in total length for High Growth Case but the Timah-Tasoh dam only is recommended for Low Growth Case. The total construction cost is estimated to be M$43 x 10^6 for High Growth Case and M$12 x 10^6 for Low Growth Case.

The major problem area in the Kedah river basin is Kuala Nerang. The recommended plan is channel improvement for river stretches of 18 km in total length. The construction cost is M$15 x 10^6.

The major problem area in the Muda river basin is Kuala Ketil. The recommended plan is channel improvement for river stretches of 50 km in total length. The construction cost is estimated to be M$37 x 10^6.

The major problem area in the Perai river basin is a part of Butterworth. Reform of a swamp as a retarding basin upstream of the Perai barrage is recommended. The construction cost is estimated to be M$5 x 10^6.

The Pinang river floods Georgetown. The recommended plan is channel improvement of 2.4 km in length. The construction cost is estimated to be M$39 x 10^6.

In High Growth Case, total investment cost is M$139 x 10^6. Annual equivalent of flood damage of M$20 x 10^6 can be reduced by M$14 x 10^6. Out of population of 33,500 in 2000 in average flood affected area, 23,300 is protected. The value of internal rate of return ranges between 11.1% and 18.4%. In Low Growth Case, total investment cost is M$107 x 10^6. Annual equivalent of flood damage of M$11 x 10^6 is reduced by M$6 x 10^6. Out of population of 29,900 in 2000 in average flood affected area, 16,000 is protected. The value of internal rate of return ranges between 7.6% and 12.9%.

6. WATER POLLUTION ABATEMENT PLAN

It is expected that rivers will be polluted with increase in water use in the future, though the rivers in the Region are generally clean at present.

It is assumed that BOD concentration should not be more than 5 mg/l in river stretches where intakes are located and 10 mg/l in other rivers. The measures to attain this standard are the improvement of purification method in all the rubber factories, palm oil mills and sugar factories and sewerage development in large towns. There is no significant measure to reduce pollutant load from small towns and rural areas.

It is recommended that all the rubber factories, palm oil mills and sugar mills should be encouraged to install adequate treatment facilities of their effluent. Total treatment capacity to be installed by 2000 is estimated to be 26,400 m^3/d.

It is also recommended that sewerage system be established in Kangar, Alor Setar, Sg. Petani and Kulim in order to maintain BOD concentration in the rivers below 10 mg/l. Furthermore the sewerage development for Butterworth and Georgetown should be continued as scheduled.

By undertaking the recommended measures, the assumed water quality standard can be ensured in all the rivers in the Region. If no measure is taken, 54 km of river stretches will be polluted. The recommended sewerage systems will provide service to a population of 553,000 in High Growth Case and 356,000 in Low Growth Case. The recommended plan should be implemented from the viewpoint of preservation of environmental quality and improvement of public health, though it can hardly be justified from the economic point of view.

The public development expenditure for the recommended sewerage development is estimated to be M$758 x 10^6 for High Growth Case and M$349 x 10^6 for Low Growth Case, the difference in the amount is attributable to the difference in projected population in the towns.

The private development expenditure for the rubber factories, palm oil mills and a sugar mill is estimated to be M$49 x 10^6. That for sewerage development will be M$281 x 10^6 in High Growth Case and M$38 x 10^6 in Low Growth Case.

7. LEGAL AND INSTITUTIONAL ARRANGEMENT

The Kedah-Muda-Perai river system forms an undivided complex of multipurpose water use, spanning the States of Perlis, Kedah and Pulau Pinang. As such, an integrated approach to water resources development and management only can assure equitable water use.

The Federal Government should enhance its leadership in water resources development and management in the Region, with a view to attaining the socio-economic development goal. The States of Perlis, Kedah and Pulau Pinang should be entitled with reasonable and equitable shares in the beneficial uses of water in the Region and they should collaborate in development and management of water source projects.

The impact of the Muda and Pedu dams and envisaged water source projects is large in balancing water demand and supply in the Region. All these facilities should be integratedly operated. Water in the Kedah-Muda-Perai river system should be equitably allocated among the water users in the 3 States. Every intake in a state should be controlled by the state according to a schedule of water which may be taken. Each state should undertake water rationing, which should be coordinated among the States, in an extraordinary drought, in which water deficit will take place even all the recommended source projects are implemented.

Taking into account the recommendations by NWRS, the comment is preparing the National Water Code in order to consolidate and establish uniformity in water resources administration. As an interium measure until the Code is legislated, it is recommended that the Federal Government and the 3 States Governments make a master agreement regarding the regional water resources development and management, in order to ensure an integrated administration and to encourage the federal-states coordination. The master agreement should stipulate that regional water resources master plan shall be formulated and authorized by the Federal and State Governments, allocation of water in the Region to each State shall be agreed upon by the 3 States, all source facilities in the Region shall be integratedly operated according to rules approved by the 3 States, costs for the development and management shall be equitably allocated among the Federal and the State Governments, and the Federal Government shall show an arbitration proposal at the request by one of the 3 States, if there is a dispute.

A regional water resources master plan shall be prepared and approved by the Cabinet and EXCOs of the 3 States. It should include the statements on the development targets which are envisaged by each State for public water supply, irrigation and river maintenance flow, the target water demand which each State intends to meet and water source development projects to be implemented for immediate future.

The cost allocation rule of a multipurpose project should be established by the Federal Government as a condition of federal grant and loan. An allocation method should be selected from among various methods from the viewpoint that the desired socio-economic goal is best promoted.

The principle of beneficiary-to-pay should be conducted in view of capital efficiency and promotion of people's participation in development.

The cost of water supply will increase with new facilities coming in. The average unit cost of water in the future is estimated to be M$0.58/$m^3$ for domestic use and M$1.16/$m^3$ for commercial use at 1982 constant price. It is judged that this cost is within consumers' capacity-to-pay and PWA can maintain sound account by revising the tariff from time to time. The water supply accounts in Perlis and Kedah are in deficit. It is recommended that provisions for accounting and auditing procedure be included in the Water Supply Fund Enactment of the 2 States. The rate of raw water for private intakes should be introduced because source development is necessary to maintain water for these private intakes. Present irrigation rate is too low even to cover the operation and maintenance cost of irrigation facilities. It is recommended that the irrigation water rate be gradually increased with a target that operation and maintenance cost of irrigation facilities should be met with the charge collected from farmers.

A consideration should be made in acquiring land for administrative arrangements to give priority to enter in a resettlement scheme, to provide special loan or to conduct other measures.

Increased water demand and new development are going to cause increased water deficit on the existing water users. It is necessary to expedite source development. If it is assumed that the construction work will commence in 1985 for the Jeniang system and 1986 for the Beris and Tawar-Muda dams, appropriate institutions should be established within 1984, including the National Water Resources Committee (NWRC), Federal Water Resources Division (FWRD), State Water Resources Committee (SWRC), State Water Resources Division (SWRD), and Water Resources Development and Management Corporation (WRDMC) as recommended by NWRS. It is recommended that the members of NWRC be appointed by NDPC and those of SWRC by EXCO, because they should make various judgements related to policy. WRDMC should establish a regional headquarters in the Region.

8. PART 2 STUDY

According to the Scope of Work, a feasibility study in Part 2 will be carried out for a dam project which is selected as a result of Part 1. It is recommended that the Beris dam be taken up for Part 2.

The objective of the feasibility study in Part 2 is to evaluate the Beris dam project from the technical, economic, financial and social point of view and it consists of (1) recommendation on water allocation, (2) preliminary design, (3) evaluation, and (4) preparation of an implementation program.

CONTENTS

Page

TABLES

Page

FIGURES

ABBREVIATIONS

(1) Organization/Plan

4MP	:	Fourth Malaysia Plan
DID (JPT)	:	Drainage and Irrigation Department
EPU	:	Economic Planning Unit
FELCRA	:	Federal Land Consolidation and Rehabilitation Authority
FELDA	:	Federal Land Development Authority
GSD	:	Geological Survey Department
JICA	:	Japan International Cooperation Agency
MADA	:	Muda Agricultural Development Authority
NEB (LLN)	:	National Electricity Board
NWRS	:	National Water Resources Study
PWD (JKR)	:	Public Works Department
RISDA	:	Rubber Industry Small-Holders Development Authority
WHO	:	World Health Organization

(2) Others

B	:	Benefit
BOD	:	Biochemical Oxygen Demand
C	:	Cost
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
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
H	:	Height, or Water Head
NHWL(HWL)	:	Normal High Water Level
O&M	:	Operation and Maintenance
Q	:	Discharge
Ref.	:	Reference
SS	:	Suspended Solid

ABBREVIATIONS OF MEASUREMENT

Length

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

Area

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

Volume

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

Weight

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

Time

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

Electrical Measures

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

Other Measures

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

Derived Measures

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

Money

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

CONVERSION FACTORS

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

Exchange Rate
(as average between July and December 1982)

$1 = M$2.35
¥100 = M$0.92

1. INTRODUCTION

1.1 Study Objective

The National Water Resources Study, Malaysia (NWRS) was carried out between October 1979 and October 1982 under the technical cooperation program between the Government of Malaysia and the Government of Japan, in order to make recommendations on actions to be taken by the Federal and State Governments for the integrated water resources development and management, which is needed to coordinate multifarious activities under the condition that water stress has increasingly occurred in places where previously water was found abundant for use.

NWRS recommended the National Water Policy, with which water resources development and management should support the development of all socio-economic sectors related with water resources, consistent with the national development goal. The Water Resources Development and Use Plan was proposed as a nation-wide water resources development and management program to be implemented up to 2000 in accordance with the National Water Policy. In order to ensure efficient and effective execution of the proposed program, recommendations were made on necessary arrangements in financial system, administrative actions, institutional framework, legal provisions and further studies.

NWRS was organized to formulate a macro framework for the water resources development and management, from the national viewpoint, based on an overview of present and future problems, rather than dealing with specific projects. The Water Resources Development and Use Plan presented is, therefore, a notional program to show the direction and extent of water resources development toward 2000. It is necessary to develop this notional program into firm and medium-term programs at national and regional levels, for the implementation of specific projects.

The objective of the Perlis-Kedah-Pulau Pinang Regional Water Resources Study (the Study) is to formulate an integrated water resources development and management plan for one of major water-stress regions, to the extent that the decision-making on the implementation of water resources development projects by the federal and state governments is made possible, in line with the recommendations by NWRS.

1.2 Technical Cooperation

With an intention to carry out a series of regional water resources study for the major water-stress regions which were identified by NWRS as needing early solution of pressing water shortage and other water problems, the Government of Malaysia requested the Government of Japan to undertake the Study in April, 1982.

The Scope of Work for the Study was agreed on September 25, 1982 between the Government of Malaysia and the Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of the technical cooperation programs of the Government of Japan. The Study was entrusted by JICA to the Study Team which conducted NWRS and it was started in December, 1982.

The Government of Malaysia appointed Counterpart Officers. The Government of Japan has seconded a Colombo Plan Expert in order to support the Study. The Study Team members and the officials of the two Governments who directly participated in the Study were as listed in Table 1.

To guide the Study, the Government of Malaysia established a Steering Committee chaired by Mr. Ali Abu Hassan, Director of Infrastructure and Utility Division, Economic Planning Unit (EPU) of the Prime Minister's Department.

The Steering Committee was assisted by a Technical Committee chaired by Ir. Cheong Chup Lim, Deputy Director General of the Drainage and Irrigation Department (DID). An Advisory Committee chaired by Mr. H. Tamamitsu, Deputy Director General of Planning Bureau, Ministry of Construction, Japan was established by JICA to review the findings by the Study Team. The Steering Committee and the Advisory Committee have maintained close liaison by meeting regularly to exchange views on the Study. The members of the Committees were as listed in Table 2.

1.3 Study Contents

The Study consists of two parts: Part 1 Regional Water Resources Study was carried out in 14 months between December 1982 and February 1984 and Part 2 Feasibility Study started in December 1983 will be completed in March 1985.

Part 1 of the Study contains:

(1) study on regional water demand and supply balance system including water pollution abatement planning;

(2) pre-feasibility study on the proposed 6 dams; the Badak-Temin, Sari, Durian, Tawar-Muda, Beris and Rui dams;

(3) updating of flood mitigation plans proposed by NWRS and pre-feasibility design of a channel improvement project for the lower stretch of the Muda river, which was selected as a sample area; and

(4) study on the legal and institutional arrangement for the regional water resources development and management.

The Perlis-Kedah-Pulau Pinang Region has been deemed to be most serious in water problems among the water-stress regions identified by NWRS. The Government of Malaysia has initiated some source development projects in order to alleviate immediate water problems in the region. These projects, however, are deemed to be able to meet only immediate water demand. A feasibility study of a priority project will be carried out as Part 2 of the Study, because additional source development project is urgently needed.

1.4 The Final Report for Part 1

The Final Report for Part 1 herein submitted contains the results of Part 1 Study.

1.5 Acknowledgement

The contribution to the Study by the officials of Federal and State Governments and individuals who have provided information and data, participated in discussions, given valuable advice and provided other forms of assistance to the Study are gratefully acknowledged. A heartfelt gratitude is also made to the officials of the Ministry of Foreign Affairs, Ministry of Construction and Embassy to Malaysia of the Government of Japan who have given advice and provided various supports in performing the Study.

2. RECOMMENDATIONS MADE BY NWRS

2.1 The National Water Policy

The general objective of the National Water Policy is to free the nation from water resources constraints, and thereby to contribute to national economic development, regional development, improvement of environmental quality and social well-being.

Specific objectives are described hereunder.

(1) The requisite quantity of flow will be maintained in main rivers in order to sustain normal water use and to preserve environmental quality.

(2) Public water supply will be developed to improve social well-being and to support industrial development. Irrigation development will be undertaken to attain the desired level of food self-sufficiency and to increase farmers' real income.

(3) Hydropower potential will be developed to provide self-reliance in energy to the extent possible.

(4) Water pollution will be abated from the standpoint of health and preservation of environmental quality.

(5) Flood will be mitigated to protect people's life and to reduce flood damage.

2.2 Water Resources Development and Use Plan

The Water Resources Development and Use Plan is an interpretation of the National Water Policy, with preliminarily quantified targets.

Public water supply will be provided to all people by 2000 except for the rural areas in Sabah and Sarawak, where a service factor of 90% is assumed. Industries' own water supply will be encouraged but 50% of industrial water will be supplied from public system. Rice self-sufficiency ratio will be increased from 69% to 85% by 1990 and onwards, through irrigation development.

Increased water demand should be balanced and the requisite quantity of river flow should be sustained by developing water sources in the regions of major water demand. Retaining high flow in wet season for release in dry season by storage dam is recommended to increase available water. If no more storage development is possible, it is further recommended to divert water from another river basin.

All known hydropower potential in Peninsular Malaysia should be developed in view of minimizing dependence on fossil fuel. Hydropower potential in Sabah and Sarawak should be developed to meet incremental power demand in major demand centers by 2000.

Standard concentration of biochemical oxygen demand (BOD) in rivers will be set at 5 mg/l. For the purpose of water pollution abatement in rivers, it is necessary to encourage improvement of purification system of effluent from rubber factories and palm oil mills. For the same purpose, sewerage development for 11 towns is recommended. Furthermore, for the purpose of public health improvement, sewerage projects for 20 major towns are also recommended, though not effective for river water quality conservation.

Flood mitigation measures such as channel improvement, bypass floodway, ring bund and flood control dam will be constructed and, where these measures are infeasible, non-structural measures will be undertaken, so that 50% of the flood-prone areas will be protected.

2.3 Financing System

Accelerated investment is necessary for future water resources development. Public development expenditure of the order of M$40 x 10^9 will be required for this purpose up to 2000.

Pricing policy in water resources sector should be directed to efficient and equitable allocation of financial resources: Entire costs of a public project should be paid by the beneficiaries rather than depending on general tax revenue, while government grant should be provided only if the beneficiaries are to be encouraged to participate in development activities or if subsidies to lower income people are needed.

Cost allocation rule should be established to encourage multipurpose development. Government should consider providing soft loans to those sectors which have a slow economic return.

Adverse effects inevitably induced by a water resources project should be compensated at the cost of the project. It is desirable to make compensation with equivalent goods and services, if compensation in cash is not appropriate.

2.4 Water Administration

The National Water Policy should be translated into a national water resources master plan to provide the necessary direction to sectoral water resources planning. The regional water resources master plan should be derived therefrom to demonstrate specific water resources projects, their priority ranking and implementation schedule in each region where water-related activities are affected one another.

Concept of the river maintenance flow should be established. For this purpose, an inventory should be maintained showing necessary details of water use and river flow. The Department of Environment should establish criteria for determining river water quality standard and should make recommendation on measures to be taken by various agencies responsible for controlling pollutants. Planning and design of urban drainage systems should be coordinated with relevant flood mitigation plans. Groundwater licence system should be introduced where hazardous exploitation may take place.

For planning a multipurpose project, consultation should be made among the agencies concerned on water allocation, risk in safe water supply to be accepted by individual sectors and technical standards to be applied. In formulating an inter-state project, early consultation and close cooperation are necessary among the State Governments concerned. Federal Government should play a positive role in this respect. To reconcile the national objective and state interest to each other, consultation should be made between Federal Government and State Governments concerned in preparing the national and regional water resources master plans.

2.5 Institutional Framework

It is recommended that all flood mitigation plans including those affecting urban areas be prepared by DID. The planning, construction and maintenance of the trunk drains should also be under the control of DID. The Local Government should be responsible for the urban drainage except for the trunk drains.

To ensure coordination of various sectoral activities in water resources development and management and to execute administrative actions additionally required, the establishment of institutions is recommended: A National Water

Resources Committee and a Federal Water Resources Division within the Economic Planning Unit of the Prime Minister's Department should be established to formulate and update the national water policy, to provide leadership and guidelines in preparing the national and regional water resources master plans. A State Water Resources Committee and a Water Resources Division within the State (Economic) Planning Unit should be established in each state to undertake the preparation of a regional water resources master plan and to institute and supervise water resources management. In addition, a federal statutory body, the Water Resources Development and Management Corporation should be established to implement and operate certain water source development projects.

2.6 Legal Provisions

Many of water-related matters require coordinated actions by the Federal, State and Local Governments in terms of jurisdiction, institutional arrangements as well as financing arrangements. Since law is an indispensable instrument for the efficient implementation of water resources policies and plans, and since there is a need to promote uniformity among the water-related laws enacted by State Governments, it is recommended that a comprehensive national water resources code be enacted.

2.7 Further Studies

Further studies are recommended in order to clarify more details for the decision-making. The areas requiring immediate study are as follows:

It is necessary to formulate water resources master plans in 4 regions of major water demand: The Kedah-Perlis-Pulau Pinang region needs source development including inter-state basin transfer to cope with the present water shortage and to meet increasing water demand for irrigation and in large towns. In the Kelang valley region, accelerated dam construction within the State of Selangor and transfer of water from other states are required to meet rapidly increasing water demand in large towns. An integrated water resources development should be undertaken for Melaka-Muar region, where Melaka is especially in short of water. A sizable development of rivers in the south Johor region is necessary to meet water demand in Johor Bahru, and to allow water to supply for Singapore.

Groundwater exploration should be carried out in the coastal area of Sarawak, where saline rivers hinder domestic water supply.

Power development master plan should be prepared for Sabah and Sarawak, where there is no power development program beyond 1990 and seemingly potential in the Rajang river will not be made available before 2000.

Feasibility studies including basin master planning should be carried out for Port Dickson, Kota Kinabalu and Labuan, where large water demand is expected but water resources are poor in the vicinities.

3. BACKGROUND

3.1 The Land

The Perlis-Kedah-Pulau Pinang Region (the Region) is a group of river basins in the northern part of the west coast of Peninsular Malaysia where desired water demand and supply balance cannot be attained unless they are integrated in a few number of systems: The Region of 10,325 km^2 includes the Perlis, Kedah, Merbok, Muda and Perai river basins. It roughly corresponds to the land of the States of Perlis, Kedah and Pulau Pinang. Pulau Langkawi and the Kerian river basins are not included, because they can form separate water resources systems.

The Region is dominated by a Silurian marine sedimentary basin of undulating low hills and coastal alluvial plains. The Pinang island and mountains on the eastern boundary are largely intruded by granite of after Carboniferous. Topography and geological structure are controlled by the north-northwesterly trend of fold mountain system.

Alluvial soils cover 3,140 km^2 of coastal plains, riverine flood plains and riverine terraces, and sedentary soils occur on undulating plains and in mountains.

Forest cover in the States of Perlis, Kedah and Pulau Pinang is 3,201 km^2, comprising unexploited inland productive forest of 834 km^2, regenerated inland productive forest of 335 km^2, unproductive inland forest of 1,427 km^2, mangrove forest of 94 km^2 and other forest of 511 km^2.

3.2 Water Resources

The climate in the Region is under the influence of the northeast monsoon between November and February and the southwest monsoon between April and May. Rainfall brought about by the northeast monsoon is not high, because the Region is sheltered by the Main Range, and January and February are the driest period, monthly rainfall being about 50 mm. Rainfall by the southwest monsoon reaches a peak of over 200 mm/month in May. The heaviest rainfall occurs during the inter-monsoon period of August to October, in which monthly rainfall ranges between 200 mm and 350 mm. Annual rainfall increases from the north to the south; it is 1,814 mm at Tasoh in the Perlis river basin, 2,162 mm at the Muda dam and 3,360 mm at Ladang Dublin in the Perai river basin, on an average.

Out of 22 hydrological stations operated by DID within the Region, following key stations are selected for the analysis of surface runoff, in view of relative accuracy and length of record. The Titi Konkerit Baru hydrological station in the Perlis river basin has a record since 1975, the Lengkuas hydrological station in the Kedah river basin was operated between 1946 and 1967, the Jeniang hydrological station in the Muda river has a record since 1947, though it has been affected by the operation of the Muda dam since 1968. The Ara Kuda hydrological station in the Kulim river of the Perai river system has a record since 1961. Daily discharge records of these hydrological stations are extracted from DID data bank for the 20-year period between 1961 and 1980. Interruptions are interpolated, and disturbed or doubtful records are adjusted based on rainfall record by means of a simulation model.

The estimated runoff for the period of 1961 - 1980 at the 4 key stations is summarized as monthly runoff record as shown in Tables 3 and 4. Generally, wet season is

September to December, in which 50 - 70% of annual runoff occurs. There is a minor peak in runoff in May. Driest month is February or March. Variation in annual runoff is higher in the Perlis and Kedah rivers than in the Muda and Perai rivers. It is between 47% and 163% of 20-year average in the former two rivers, but between 64% and 149% in the latter rivers.

The critical period is normally between March and July in view of water demand and supply balance in the Region. According to Tables 3 and 4 natural runoff in this period is smallest in 1977 among those between 1961 and 1980 at the Jeniang hydrological station in the Muda river. Furthermore, the 3-year period of 1977 to 1979 is the driest consecutive spell. At the Lengkuas hydrological station in the Kedah river, 1977 has the fourth smallest natural runoff in March to July and the 3-year period of 1977 to 1979 is also one of two consecutive dry spells. The hydrological condition in 1977 is regarded as the typical dry condition in this Report.

Groundwater in the Region is mostly semi-confined aquifer replenished by rain and it occurs in fissures or cracks in indurated sandstones and shales, cavities of limestones and pores in alluvial sands and gravels. Rock aquifer is generally poor in quantity except for limestone formation of Ordovician to Silurian forming the ridge of western boundary of the State of Perlis and that of Permian to Triassic on the east of the Perlis river. Alluvial aquifer in the coastal flood plains is rich in quantity but is mostly intruded by sea water. Groundwater recharge is estimated to be 750×10^6 m^3/y in total for the Region, but it is lost into the sea in a lapse of time. Assuming that pumping should not deplete groundwater storage and taking into account the probability that production well can hit applicable groundwater body, safe yield is estimated to be 91×10^6 m^3/y.

Average annual rainfall on the Region is 23,340 x 10^6 m^3, or 2,260 mm, out of which 13,300 x 10^6 m^3, or 1,290 mm returns to atmosphere as a result of evaporation and transpiration. The rest forms surface runoff of 9,290 x 10^6 m^3, or 900 mm and groundwater recharge of 750 x 10^6 m^3, or 70 mm and finally lost to the sea. This relationship by river basin is as shown in Table 5.

3.3 Socio-Economy

The state population in 1980 was 157,000 in Perlis, 1,173,000 in Kedah and 970,000 in Pulau Pinang. Annual population growth rate was 1.8% between 1970 and 1980. About a half the population in Pulau Pinang is urban population living in Butterworth, Georgetown and other towns.

Gross regional product (GRP) in 1980 at factor cost at 1970 constant price was M$168 x 10^6, or M$1,066 per capita in Perlis, M$1,254 x 10^6, or M$1,070 per capita in Kedah and M$2,221 x 10^6 or M$2,290 per capita in Pulau Pinang, according to 4MP. Annual growth rate in GRP between 1971 and 1980 was 6.5% for Perlis and Kedah and 11.6% for Pulau Pinang.

The economic structure is agricultural in the States of Perlis and Kedah and industrial in the State of Pulau Pinang. Share of the agriculture, forestry and fishing sector in GRP in 1980 was 46.9% in Perlis and Kedah and 5.9% in Pulau Pinang, while share of manufacturing sector was 6.9% in Perlis and Kedah and 37.2% in Pulau Pinang.

Major land use pattern in 1982 in the three States was forest of 4,045 km^2 (including exploited forest of 844 km^2), grassland of 168 km^2, swamp of 70 km^2, agricultural land of 4,838 km^2 and miscellaneous land of 2,139 km^2.

Tree crops are widely grown for export. Total planted area in 1982 was 106,800 ha for rubber, 14,000 ha for oil palm, 27,400 ha for coconuts and 1,000 ha for cocoa. Annual production in 1980 was 259,700 tons of rubber in dry rubber content, 167,600 tons of fresh fruit bunch of oil palm, 150 tons of copra and 26 tons of dry cocoa beans.

Planted area of paddy in 1981/82 was 155,000 ha in main season and 108,600 ha in off season. Annual paddy production of 963,800 tons in the same year was more than 3 fold of local consumption which is estimated to be 276,000 tons.

3.4 Water Use

3.4.1 Domestic and industrial water supply

Public water supply is administered by the Water Supply Division of Public Works Department (PWD) of the State Government in the States of Perlis and Kedah, and by the Pulau Pinang Water Authority (PWA), a state statutory body applying a commercial accounting system in the State of Pulau Pinang.

The state land is divided into several water supply areas in view of location of demand centers and intakes for the purpose of management. Each water supply area encompasses some urban and rural water supply systems, which supply treated pipe water connected to individual taps. Number of water supply areas is 8 in the State of Perlis, 19 in the State of Kedah and 4 in the State of Pulau Pinang. Some of the water supply areas will be integrated in some others in the near future.

Population served by PWD/PWA water supply system in 1982 is estimated to be 123,800 for the State of Perlis, 549,000 for the State of Kedah and 857,900 for the State of Pulau Pinang. The treatment capacity of PWD/PWA water supply system in 1982 is estimated to be 7.8×10^6 m^3/y for Perlis, 76.6×10^6 m^3/y for Kedah and 112.4×10^6 m^3/y for Pulau Pinang.

Under the Rural Environmental Sanitation Program (RESP) with materials and technical advices from MOH, the state governments have installed untreated water supply systems in interior and isolated rural areas, by either taking water from small streams or digging shallow wells equipped with hand pumps. Population served by RESP system in 1982 is estimated to be 11,900 for the State of Perlis, 221,400 for the State of Kedah and 4,700 for the State of Pulau Pinang.

The service factor of PWD/PWA and RESP systems together makes up 70% in the State of Perlis, 68% in the State of Kedah and 87% in the State of Pulau Pinang.

3.4.2 Irrigation

The Drainage and Irrigation Departments (DID) of the Federal and State Governments are responsible for irrigation. Irrigation project is implemented as a state, federal re-imbursable or federal project.

Minor irrigation schemes have been developed since 1950s. There were 63 positive irrigation schemes of 26,000 ha equipped with gravity or pump irrigation system and 9 control drainage schemes of 6,600 ha in 1982. Positive irrigation schemes of less than 500 ha in size are 54 in number, but their total area is only 8,100 ha or 31% of total area of positive irrigation schemes.

Two-crop system is normal in the positive irrigation schemes. Cropping period is between September and January/February in the main season and between March and August in the off season.

Low production due to poor water management is common among the minor irrigation schemes. The Study on the Intensification of Irrigated Agriculture in Kedah and Perlis, 1981, recommended measures for improvement of minor irrigation schemes with emphasize on tertiary development including an intensification of irrigation and drainage canal density. Aiming at improving water management, the Study on Upgrading of Irrigation and Drainage Schemes in P. Pinang, 1982, recommended the increase of canal density and rehabilitation of existing facilities.

Average annual paddy production between 1973/74 and 1981/82 is estimated to be 156,000 tons for the positive irrigation schemes and 22,500 tons for the control drainage schemes.

The Muda irrigation project, constructed between 1965 and 1970, commands 95,800 ha of the Kawasan Muda in the coastal plain of the States of Perlis and Kedah. The Muda Agricultural Development Authority (MADA), established based on the MADA Act, 1972 is responsible to promote, stimulate, facilitate and undertake economic and social development in the Kawasan Muda and to plan and undertake within the Kawasan Muda such agricultural development as may be assigned to MADA by the State Authority of the States of Kedah and Perlis.

A transplanting system with mixed nursery is predominant in the MADA area. Growing period of paddy is 130 days starting in October - December for main season cropping and 140 days starting in April - June for off season cropping. The cropping period tends to delay due to insufficient water and off season cropping could not be performed in 1978 due to prolonged cropping calendar resulting from consecutive dry spells.

Average annual paddy production in the MADA area between 1973/74 and 1981/82 was 773,000 tons.

3.4.3 Inland fishery

There were 116 ha of constructed ponds and 34 ha of tin mining pools which were used for freshwater fish culture in 1979. Annual water requirement in these ponds is estimated to be $1 \times 10^6 - 2 \times 10^6$ m^3.

3.4.4 Inland navigation

River traffic is quite seldom in the Region. A limited number of sampans ascend the Perlis river up to Kg. Tebing Tinggi. Some marine fishing boats are found in the estuary of the Kedah river, but passage through the lock of the Kedah barrage is scarce. Cargo boats ascend the Perai river to feed factories and warehouses which are located 8.5 km upstream of the river mouth. There are marine fishing boats in the rivers in the Pinang island.

3.5 Water Quality

The water quality monitoring program was initiated by the Department of Environment (DOE) in March 1978. The Region is delineated in the water quality control regions 1 to 7, which are under the branch of DOE in Butterworth. There are a number of water quality monitoring stations in the Region. The monitoring has been carried out every year since 1978 at 55 to 68 stations. Water quality in major rivers in the Region is described based on the results of above-mentioned monitoring and a water quality survey which was conducted by the Study Team with an assistance by DOE in January 1983.

The Perlis river is clean to mildly polluted. The concentration of biochemical oxygen demand (BOD) is normally less than 4 mg/l and concentration of suspended solid (SS) is high near Kangar. Concentration of BOD, SS and ammoniacal nitrogen (NH_4-N) are sometimes high in a limited upper stretch. They are probably attributable to the operation of a sugarcane estate and a sugar mill.

The Kedah river is clean to mildly polluted. BOD concentration near Alor Setar sometimes exceeds over 5 mg/l. SS concentration is high in the Pdg. Terap river, probably due to opening up of a sugar estate. BOD concentration in the Pdg. Terap river was high near a sugar mill in 1978, but it is less than 5 mg/l, after the sugar mill installed purification facilities being advised by DOE.

The Merbok river is most polluted among the rivers in the Region, due to the operation of 3 rubber factories and effluent from Sg. Petani. Concentrations of BOD, COD and NH_4-N are very high in the tributaries where the rubber factories are located and high concentration of NH_4-N is observed below Sg. Petani.

The Muda river is clean owing to ample river flow in spite of existence of several rubber factories.

The Perai river is clean, because discharge is high and most pollutant sources discharge effluent into the sea being located near the sea coast.

The Juru river is highly polluted with the effluent from Bukit Mertajam, a rubber factory and animal husbandry.

The Jejawi river is mildly polluted with the effluent from towns, rubber factories and animal husbandry.

3.6 Flood Problem

The flood problems and countermeasures are studied for the Perlis, Kedah, Muda, Perai and Pinang rivers, of which total basin area of 9,980 km^2 covers 90% of the Region.

In the Perlis river basin, the flood in September 1976 was the worst one. The north-south running tributaries inundated and Kangar was mostly flooded. The flooded area was 49.2 km^2. Assuming the land use and population in 1982, it is estimated that total flood damage was M$10 x 10^6 and affected population was 30,000. The other remarkable floods were those in July 1982 and September 1972.

In the Kedah river basin, a recorded maximum flood occurred in December 1975. The river inundated at several places upstream of the Pelubang barrage. Kuala Nerang was seriously affected. The flooded area was 35.2 km^2. Assuming the land use and population in 1982, it is estimated that flood damage was M$3.5 x 10^6 and population affected was 7,500. Other remarkable floods occurred in November 1979 and October 1980.

In the Muda river basin, a large flood occurred in December 1973. The lower stretch of the Muda river and the middle stretch of the Ketil river entirely inundated. Kuala Ketil was seriously affected. The flooded area was 142.5 km^2. Assuming the land use and population in 1982, it is estimated that flood damage was M$18.3 x 10^6 and population affected was 51,700. Other remarkable floods were those occurred in November 1972 and October 1980.

In the Perai river basin, a flood in September 1971 caused flooding of 17.4 km^2 below the confluence of the Kereh river and the Kulim river and a part of Butterworth was affected. Assuming the land use and population in 1982, it is estimated that flood damage was M$1.9 x 10^6 and population affected was 8,200.

In the Pinang river basin, the flood in October 1980 flooded 2 km^2 mostly in Georgetown. Assuming the land use and population in 1982, it is estimated that flood damage was M$3 x 10^6 and population affected was 13,600.

3.7 Sewerage System

Georgetown has a sewerage system which discharges untreated sewage into the sea. The served population is estimated to be 217,000, or 78% of total population in Georgetown of 278,000.

Bandar Bayan Baru has a sewerage system discharging stabilized sewage into the mouth of Kluang river. The served population is 5,000, or 20% of total population of 25,000. A sewerage system with treatment plants is under construction for Butterworth and Bukit Mertajam.

The installation of septic tank is compulsory by regulation in unsewered urban areas, while domestic sewage in rural areas is directly discharged into water course or onto land.

3.8 Existing Water Resources Facilities

The Perlis river is predominantly utilized by minor irrigation schemes. There are 2 minor irrigation schemes of 1,286 ha in total area along the main stream and 14 minor irrigation schemes of 2,431 ha in total area along tributaries. Major water source for water supply in Kangar is the irrigation canal of the Muda irrigation project but groundwater is conjunctively utilized. PWD operates 8 production wells which were drilled by GSD in alluvial and limestone aquifers in the Arau well field since 1955. In 1982, groundwater of 5,400 m^3/d was extracted from 7 wells out of the 8. In order to increase groundwater production, 6 additional wells were drilled in limestone aquifer in the Arau well field in 1982.

The Muda and Pedu dams are operated to supply water to the MADA area. The Muda dam completed in 1968 with an active storage capacity of 160 x 10^6 m^3 conveys water from its catchment area of 984 km^2 in the upper Muda river basin through the Saiong tunnel to the Pedu river, an upper tributary of the Kedah river. The Pedu dam completed in 1969 with an active storage capacity of 1,049 x 10^6 m^3 regulates the water from the Muda dam and inflow from its own catchment area of 171 km^2. The regulated outflow from the Pedu dam is discharged into the Kedah river.

The Pelubang barrage completed in 1969 takes water in the Kedah river, which is augmented by the outflow from the Pedu dam. Water diverted by the barrage into a canal is divided by 2 regulators to the north canal and the central canal to feed the MADA area. The central canal running southward bifurcates at the Guar Kepayang regulator into the Tokai and southern branch canals. Additional sources of water are the Tanjong Pauh river, a tributary of the Kedah river, with a catchment area of 453 km^2 joining the northern canal 6 km downstream of the Pelubang regulators and the Arau river, a tributary of the Perlis river, of 97 km^2 in catchment area connected with the downstream end of the northern canal. There are 2 minor irrigation schemes of 432 ha in total area depending on the southern branch canal, 3 minor irrigation schemes of 1,427 ha in total area in the Temin river and 3 minor irrigation schemes of 221 ha in total area in other tributaries. Number of intakes for water supply is 6 depending on the irrigation canals of MADA, 2 in the main stream and 3 in tributaries. The Kedah barrage located below Alor Setar is a gated tidal barrage completed in 1970.

There are 2 minor irrigation schemes of 231 ha in total area and 6 water supply intakes taking water from tributaries of the Merbok river, but there is no intake in the main stream of the river.

The irrigation intakes in the Muda main stream are located in the river stretch of about 35 km in length up-stream of the Muda barrage. On the right bank, or, Kedah side, there are 3 minor irrigation schemes of 2,704 ha in total area, and on the left bank, or Pulau Pinang side, there are 4 minor irrigation schemes of 8,611 ha in total area. Furthermore, the Pinang Tungal minor irrigation scheme of 4,673 ha in the Perai river basin is supplemented with water from the Muda river. The minor irrigation schemes in tributaries of the Muda river are 15 in number and 1,440 ha in total area. The River Muda Canal conveys water from the main stream of the Muda river to the Sg. Dua waterworks, which supplies domestic and industrial water to major water demand centers in the State of Pulau Pinang. The waterwork also utilizes water from the Perai river. In addition to the River Muda Canal system, there are 6 water supply intakes; one in the main stream and 5 in tributaries.

In addition to the Pinang Tungal scheme, there are 10 minor irrigation projects of 1,122 ha in total area in the Perai river system. Two water supply intakes in the Perai river and one in the Juru river are interconnected with the Sg. Dua waterworks system. The Perai barrage was completed in 1981 in order to mitigate flood affecting Butterworth by retaining water in a swamp in the middle reaches of the Perai river.

There are 2 minor irrigation schemes of 1,126 ha in total area and 24 water supply intakes in the Pinang island. The Ayer Hitam dam has been operated since 1962 with an active storage capacity of 2×10^6 m^3 for the purpose of water supply in the Pinang island. The catchment area is 25 km^2. The water supply system in the Pinang island is fed by the Sg. Dua waterworks system through a submarine pipeline.

3.9 On-Going Water Resources Development Projects

Herein described on-going projects are major projects which are either committed for implementation or under construction.

There is no dam in the Perlis river basin. Two dams are being investigated for the purposes of flood mitigation and irrigation. The Timah-Tasoh dam site is located just downstream of the confluence of the Timah and Tasoh rivers with a catchment area of 150 km^2. The active storage capacity will be 37 x 10^6 m^3 if implemented. The Arau dam with a catchment area of 58 km^2 is being envisaged in the Arau river. The active storage capacity will be 25 x 10^6 m^3.

The Ahning dam is planned in a tributary of the Kedah river for the purposes of water supply to Alor Setar and hydropower generation. The catchment area is 120 km^2. It is envisaged that increased water demand at Alor Setar up to 1995 is met by regulating river flow with an active storage capacity of about 200 x 10^6 m^3.

The on-going Muda II irrigation project with a financial assistance from IBRD is regarded as the initial stage of a tertiary development program for the whole MADA area. When the tertiary development including the construction of tertiary canals, drains and access roads is completed, the canal density will be increased from 10 m/ha to 30 m/ha. MADA will employ a separate nursery system instead of mixed nursery system in the area where the tertiary development is completed, and also will introduce direct seeding system for the off season cropping in 26% of total area. The cropping calendar after the tertiary development will be the main season cropping from August/September to December/ January and off season cropping from February - April to July/August under the transplanting system with separate nurseries, but the off season cropping from March to August under the direct seeding system. The tertiary development has been implemented for 3,360 ha at the end of 1982, and it will be completed for 40% of the MADA area by 1990 and for the whole MADA area by 2000. It is expected that production cost will be largely reduced by the tertiary development.

Water shortage in the MADA area will not be eliminated unless additional water resources are developed, even though the tertiary development will reduce water demand to some extent. Increased water use in tributaries may worsen the water shortage.

A feasibility study is being carried out for the Jeniang diversion system which has been envisaged to relieve water shortage in the MADA area as well as to enable increased water use in the Kedah river system by diverting water from the Muda river to a southern part of the MADA area. The proposed Jeniang weir is constructed in the midstream of the Muda river, where the catchment area is 667 km^2. A diversion canal is excavated between the weir and the proposed Naok dam which will retain water in the active storage space of 27×10^6 m^3 during the wet season for the use in the dry season. A canal is constructed to convey water from the Naok dam to the central canal a little upstream of the Guar Kepayang regulator, which commands 33,400 ha in the southern part of the MADA area.

The Mengkuang dam is under construction in the State of Pulau Pinang. It is a pumped-storage dam of 23.7×10^6 m^3 in active storage capacity. By utilizing water in the Kulim river and the River Muda Canal, the dam will contribute more water to the Sg. Dua waterworks system.

Principal feature of the on-going source development projects is summarized in Table 6.

3.10 Relationship Among River Systems

Some river systems are divided or interconnected from the viewpoint of water demand and supply balance. The Perlis river system is divided into the main system of Temanggang, Korok and other tributaries which feed the northwestern part of the State of Perlis, and the Arau river and northern half of the Gial river, which flow into the MADA area. Herein the former is called the Perlis river system and the latter is regarded as a part of the Kedah river system.

The Kedah river system is characterized by the irrigation system of MADA, which integrates the Kedah river, and the abovementioned Arau river and northern Gial river. The Pedu river, an upper tributary of the Kedah river, is fed by the Muda dam in the Muda river. The Kedah river system is herein defined as all the river systems which are flowing into the MADA area, including those in the catchment area of the Muda dam.

The Muda river system is interconnected with the Perai river system through the River Muda Canal and the irrigation canals of the Pinang Tungal minor irrigation scheme. These 2 river systems also supply domestic and industrial water to the Pinang island through a submarine pipeline system. The Muda dam discharges insignificant volume of water downstream. The Muda-Perai river system is defined as the Muda river system, the Perai river system and the river systems in the Pinang island, excluding the catchment area of the Muda dam.

The Kedah river system and the Muda-Perai river system will be interconnected, if the Jeniang system is implemented. In this sense, the two river systems together are herein called the Kedah-Muda-Perai river system.

4. FUTURE WATER DEMAND AND ASSOCIATED PROBLEMS

4.1 Socio-Economic Projection

Population and gross regional product (GRP) projected by NWRS are modified with the consideration described hereunder.

Bandar Bayan Baru and Bandar Seberang Jaya are new towns under construction in the State of Pulau Pinang. According to information by the Penang Development Corporation, planned population by 2000 is 250,000 in each the town. Immigration into these towns is taken into account in modifying the projected population. Populations in the State of Perlis and the State of Kedah are separately projected, while the two states were put together in the previous projection. Total population in Malaysia remains as projected by NWRS. As a result of these adjustments, population projected for 2000 is increased by about 300,000 for the State of Pulau Pinang, but a little reduced for the States of Perlis and Kedah. Projected population by state is as shown in Table 7.

In projecting GRP, NWRS assumed annual growth rate of gross domestic product (GDP) to be 7.6% for 1980 - 1985, 8.4% for 1985 - 1990 and 7.5% for 1990 - 2000, following 4MP, which set target for 1985 and 1990. NWRS made another projection assuming annual growth rate of GDP to be 7% for 1980 - 1985, 6% for 1985 - 1990 and 5% for 1990 - 2000, for reference. World-wide economic depression still persists and it is likely to continue to affect Malaysia's economy. According to the Annual Report 1982 by Bank Negara, Malaysia, the growth rate of GDP was 6.7% in 1981 and 4.6% in 1982. Taking into account these conditions, this projection is adjusted assuming annual growth rate of 6% for 1980 - 1985, 5% for 1985 - 1990 and 4% for 1990 - 2000. Hereinafter the condition following 4MP is called High Growth Case and that assuming the lower economic growth is named Low Growth Case. Projected GDP by state is shown in Table 8 for High and Low Growth Cases.

The Mid-Term Review of 4MP is being prepared by EPU. Preliminary values of population and GDP by state for 1980 and 1990 were provided by EPU in July 1983 as shown in Table 9. A cross check resulted that domestic and industrial water demand and other relevant figures derived from the abovementioned values fall between those estimated for High and Low Growth Cases. No modification is, therefore, made of the estimated values of population and GDP for High and Low Growth Cases.

4.2 Domestic and Industrial Water Demand

As a preliminary target for the public water supply system development, the service factor for domestic water supply in 2000 is assumed to be 100% in High Growth Case and 96% for Perlis and Kedah, and 97% for Pulau Pinang in Low Growth Case. The service factor for industrial water supply is assumed to be 50% for Perlis and Kedah and 90% for Pulau Pinang. The target for 2000 corresponds to the treatment capacity of PWD/PWA water supply system of 29 x 10^6 m^3/y for Perlis, 178.3 x 10^6 m^3/y for Kedah and 432.2 x 10^6 m^3/y for Pulau Pinang in High Growth Case, and 15.1 x 10^6 m^3/y for Perlis, 90.3 x 10^6 m^3/y for Kedah and 300 x 10^6 m^3/y for Pulau Pinang in Low Growth Case.

Domestic and industrial water demand projection made by NWRS is modified according to the modified projection of population and GRP. The adjusted domestic and industrial water demand projection is summarized in Table 10. The projection under High Growth Case shows that the total domestic and industrial water demand of 177 x 10^6 m^3 in 1982 will increase to 709 x 10^6 m^3 by 2000 and the proportion of industrial water demand will increase from 44% to 64% in the same period. If Low Growth Case is assumed, total water demand will be 424 x 10^6 m^3 and the proportion of industrial water demand will be 54% in 2000.

4.3 Irrigation Development Potential

Out of the existing positive minor irrigation projects of 26,000 ha, 900 ha will be converted to other land use, because of either low efficiency in paddy production or urban development.

There are 32,500 ha of rainfed paddy, in which crop yield is low and unstable. DID had steadily developed minor irrigation schemes by converting rainfed lands, in order to increase and stabilize rice production as well as to narrow down the disparity in farmers' real income between the MADA area and fringe areas.

According to 4MP, 6,400 ha of minor irrigation schemes will be implemented by 1985 in the Region.

Potential area for additional development of minor irrigation projects is estimated to be 8,000 ha in the Region, assuming that the potential projects larger than 20 ha in size can be implemented if water is enough for a cropping intensity higher than 150%, which is estimated to be marginal from the viewpoint of economic viability. It is assumed that these potential projects will be implemented by 2000.

The MADA irrigation area of 95,800 ha in 1982 is assumed to reduce by 2,000 ha by the on-going tertiary development and by 800 ha with expansion of residential area by 2000.

Map showing existing and future irrigation area is as shown in Figs. 1 and 2. The projected irrigation area by river system by state is as shown in Table 11.

4.4 Irrigation Water Demand

Irrigation water demand is estimated by means of a plot-to-plot irrigation model and assuring a conveyance efficiency of 75% - 80% for MADA area and 65% - 70% for other area based on actual records.

The projected irrigation water demand is summarized by river system by state as shown in Table 12. The present water demand is about 2.1×10^9 m^3/y and it will increase to 2.2×10^9 m^3/y. In the MADA area, irrigation water demand will reduce from 1.6×10^9 m^3 to 1.5×10^9 m^3 mainly owing to the application of the separate nursery system.

4.5 River Maintenance Flow

NWRS recommended to sustain the river maintenance flow in rivers at all times except during extraordinarily dry period.

The river maintenance flow is the minimum discharge which is required to maintain water depth, flow velocity, water quality, channel stability, aquatic eco-system and scenery to the extent necessary for navigation, fish catch, operation and maintenance of intakes, maintenance of river facilities, sea water repulsion, prevention of estuary clogging, conservation of groundwater, preservation of riparian land and people's amenity.

River channels are stable even at estuaries and instream water use is quite limited in the Region. On the other hand, man-made water pollution has developed in some rivers and it will increase with population growth and industrial development. The requirement for the river maintenance flow is investigated from the viewpoint of conservation of river water quality, particularly, BOD concentration which indicates man-made organic pollution.

It is assumed that BOD concentration in the river should not be higher than 5 mg/l at domestic and industrial water supply intakes and irrigation intakes and 10 mg/l in all river stretches for the preservation of environmental quality.

Assuming that the sewerage development and improvement of purification system in sugar mills, rubber factories and palm oil mills are implemented as proposed in Chapter 8, it is estimated that the above-mentioned limit is not exceeded in the tributaries, and upper and middle reaches of the main stream of rivers, even if runoff lowers to the smallest 5-day mean natural flow between 1961 and 1980, but lower stretches of some rivers are problem areas: Maximum BOD concentration projected to exceed the above-mentioned limit for 2000 is 17 mg/l below Kangar in the Perlis river and 16 mg/l below Alor Setar in the Kedah river in High Growth Case and 14 mg/l below Kangar in the Perlis river and 11 mg/l below Alor Setar in the Kedah river in Low Growth Case.

In order to reduce maximum BOD concentration below 10 mg/l for the purpose of preservation of environmental quality, it is necessary to sustain 1.5 m^3/s of discharge in High Growth Case and 0.4 m^3/s of discharge in Low Growth Case below Kangar in the Perlis river and 6.2 m^3/s of discharge in High Growth Case and 2.3 m^3/s of discharge in Low Growth Case below Alor Setar in the Kedah river by augmenting river flow in dry season.

4.6 Water Demand and Supply Balance Model

The model representing the river and canal systems and intakes and outlets is illustrated in Figs. 3 and 4. The surface water abstruction for domestic and industrial water supply is turbulated by intake for 1982, 1985, 1990 and 2000 in ANNEX B. Irrigation water demand by irrigation scheme is calculated from the projected irrigation area by scheme and projected 10-day field irrigation water requirement by Rainfall Zone in ANNEX D.

The calculation starts with the water demand and supply balance in each tributary on 5-day basis. The uppermost intake takes natural flow there. If natural flow is larger than water demand, the remaining natural flow runs downstream. If otherwise, all natural flow is taken and the difference between water demand and natural flow is water deficit at the intake. Certain return flow is discharged into the river at the outlet. Water available at next intake is natural flow from the catchment area between upper intake and the objective intake, natural flow unused at the upper intake, and return flow from the outlet located upstream. The discharge from each tributary into the main stream is obtained by repeating the above-mentioned analysis for all the stretch of the tributary. The water deficit in a tributary is a sum of water deficits at all the intakes in the tributary.

The same calculation is carried out from the upstream end along the main stream. Inflow into a stretch of the main stream comes from the upper adjacent stretch and tributaries flowing into the objective stretch and from own catchment area of the stretch. Hence, water deficit at any intake of the main stream is calculated. The river maintenance flow, if needed, is added to the water demand.

The water deficit downstream of a dam is initially calculated assuming that there is no discharge from the catchment area of the dam and then it is deducted by outflow from the dam, which can minimize water deficit by means of a given active storage capacity.

4.7 Water Deficit

Water deficit in 1982, 1990 and 2000 is estimated for the Perlis, Kedah, Muda-Perai river systems by means of water demand and supply balance model, assuming that only the existing dams such as the Pedu, Muda and Ayer Hitam dams are operated. The calculation was conducted based on 5-day runoff record for 20 years between 1961 and 1980 and 10-day water demand data.

Groundwater use is assumed only for domestic and industrial water supply within the smaller volume between the estimated safe yield and rural water demand in each water supply area.

The runoff at a section of the river is the natural flow deducted by certain water which is determined by the volumes and locations of water demand upstream the section, but it is supplemented by the regulated outflow from existing dams. Assuming the hydrological condition in 1976 and 1977 and water demand in 2000, the water demand at the Pelubang barrage is superposed on the runoff including net water output of the Pedu and Muda dams to illustrate water deficit in the upper diagram of Fig. 5, and similar illustration in the pondage of the Muda barrage is shown in the lower diagram of Fig. 5.

Runoff occurring in the main stream is the natural runoff deducted by water withdrawn by water uses in the tributaries. It reduces with increase in water uses in the tributaries. A part of runoff in the main stream is available for use, but the remainder is wasted to the sea as flood flow. The difference between the water demand in the main stream and runoff available in the main stream is water deficit. The water output from a dam reduces water deficit. A relationship among estimated river runoff, water demand, water output from the existing dams and water deficit in the main stream, under the hydrological condition in 1977, is illustrated in Fig. 6 for High Growth Case and Fig. 7 for Low Growth Case.

In the Perlis river, water deficit in the main stream is 3×10^6 - 4×10^6 m^3 up to 1990 and it gradually developes 29×10^6 m^3 by 2000. The difference in water deficit between

High and Low Growth Cases is insignificant, because domestic and industrial water demand is small. It is estimated that all water deficit can be met by the on-going Timah-Tasoh dam up to 2000.

In the Kedah river system, a large water deficit occurs most of the year, because water demand is much larger than total river runoff in the dry year. Water deficit in the main stream is already high of 312 x 10^6 m^3, or 19% of total main stream water demand in 1982. It increases to 463 x 10^6 m^3, or 26% of total water demand by 2000 in High Growth Case and 398 x 10^6 m^3, or 24% of total water demand in Low Growth Case. The decrease in water demand in the Muda irrigation project between 1982 and 2000 is attributable to the progress of tertiary development.

In the Muda-Perai river system, natural flow deducted by the inflow into the Muda dam is 2,741 x 10^6 m^3. Water deficit is large between March and October, but there is a large volume of surplus runoff between November and January even in 2000. Water deficit in the main stream is 28 x 10^6 m^3, or only 6% of total water demand in 1982 but it will increase to 164 x 10^6 m^3, or 19% of total demand in High Growth Case and 107 x 10^6 m^3, or 16% of total water demand by 2000. The increase in water demand between 1982 and 2000 is mostly due to increase in domestic and industrial water demand.

Water deficit under a serious drought is important to determine the capacity of source facilities and also to consider the drought hazard by individual event, but long-term average of water deficit is rather important in estimating the economic benefit. As an average under the hydrological condition between 1961 and 1980, the water deficit in the main stream of the Kedah river is estimated to be 282 x 10^6 m^3 in 1982, 347 x 10^6 m^3 in 1990 and 386 x

10^6 m^3 in 2000 for High Growth Case, and 340 x 10^6 m^3 in 1990 and 357 x 10^6 m^3 in 2000 for Low Growth Case, being in the same order as that under the 1977 hydrological condition, because water deficit occurs every year. The average water deficit in the main stream of the Muda river is estimated to be 5 x 10^6 m^3 in 1982, 8 x 10^6 m^3 in 1990 and 26 x 10^6 m^3 in 2000 for High Growth Case, and 6 x 10^6 m^3 in 1990 and 12 x 10^6 m^3 in 2000 for Low Growth Case, being much smaller than that under the 1977 hydrological condition, because water deficit takes place only once in several years.

The existing and future minor irrigation schemes are herein classified into those in the main stream and tributaries. They are referred to in Tables and Figures as the main minor and tributary minor. The minor irrigation schemes in the main stream are those taking water from a river stretch or a canal which is located downstream of the outlet of the existing or assumed source project and the others are the minor irrigation schemes in tributaries. The existing and future minor irrigation schemes in the main stream in the Kedah river system are either located in the river stretch between the Pedu dam and Pelubang barrage or taking water from the MADA canal system. There is no development plan of minor irrigation scheme in the main stream of the Muda river.

The cause of water deficit and the area affected by the water deficit are not always identical each other. The causes of and areas affected by water deficit in the main stream of the Kedah and Muda rivers are analyzed, assuming that the existing and on-going source projects except for the Jeniang system are being operated. The water deficit already existing in 1982 cannot be physically divided into causes and it is regarded as caused by the existing projects in proportion to water demand. For the future years, total incremental water deficit after 1982 deducted by that which is calculated assuming that water demand in a purpose does not increase is the incremental water deficit caused by the purpose. The water deficit which affects a purpose is assumed to be proportional to water demand of the purpose. The resulted average annual water deficit by cause of water deficit by area affected by water deficit is summarized in Table 13 for High Growth Case and in Table 14 for Low Growth Case.

5. PROPOSED AND POTENTIAL DAMS

5.1 Data and Assumptions

Sizing, design and cost estimate for the proposed 6 dams are conducted at a pre-feasibility level based on the estimated runoff at the dam sites between 1961 and 1980, projected water demand, 1/10,000 maps for the reservoir areas, 1/1,000 maps for the dam sites, results of geological drilling at the dam sites, and results of land use survey in the reservoir areas.

The design and construction cost estimate for each dam are made for 4 different elevations of reservoir normal high water level (HWL). The net water output from each dam of varying HWL under the hydrological condition of 1977 is estimated assuming preliminary values of water deficit which should be met by the dam. Then, a relationship between HWL and construction cost/net water output is obtained. The optimum HWL is regarded as that at which the value of construction cost/net water output is the lowest. The optimum size is actually determined at the physical maximum for all the proposed dams except for the Sari and Rui dams, because the value of construction cost/net water output monotonously increases as HWL increases. The optimum size of only the Sari and Rui dams is determined to be smaller than the physical maximum, according to the above-mentioned procedure.

5.2 The Badak-Temin Dam

The proposed Badak-Temin dam site is located in a wide flat valley of upper Devonian to Triassic sandstones, shales and siltstones with fluvial valley deposit of medium sand, 500 m downstream of the confluence of the Temin and Badak rivers, tributaries of the Kedah river, being accessible by an all-weather motorable road between Changlun and Sintok.

As shown in Fig. 8, the proposed reservoir area is mostly encompassed by rubber plantations of RISDA and FELDA and is leased to the Abudullar Ghaffer Mining Bhd. in the southeastern end. PWD is constructing a new road across the proposed reservoir area. Northern half and southeastern part of the area are located in a forest reserve. There is a plan to establish the 6th University on the east of the rubber plantation. About 60% of the proposed reservoir area is classified as the probable and possible mining lands according to GSD.

Annual inflow from the catchment area of 112 km^2 is estimated to be 58 x 10^6 m^3. The active storage capacity of the reservoir of 58 x 10^6 m^3 in a drawdown of 8.5 m can regulate 30 x 10^6 m^3 of water if the normal HWL is set at El. 45 m.

The proposed dam is a combination of a rockfill dam of 927,000 m^3 and a concrete gravity dam of 67,000 m^3. It is 29 m in the maximum height and 1,013 m in crest length as shown in Fig. 14. The dam crest is set at El. 50 m. The concrete spillway section is placed at the middle of the dam. It is a free overflow spillway of 54.0 m in effective width. A river outlet having 2 units of 1.2 m dia. outlet valves is installed in the concrete section. In view of wide valley bottom, a multiple stage diversion method is envisaged for the construction of dam. Three saddle dams are constructed with total volume of 462,000 m^3.

The total investment cost is estimated to be M$149.2 x 10^6 including M$123.0 x 10^6 of cost for construction work and M$26.2 x 10^6 of land acquisition cost at 1982 constant price level.

5.3 The Sari Dam

The proposed Sari dam site is located in a narrow valley of Triassic to Jurassic sandstones, shales and siltstones of the Sari river, a tributary of the Kedah river, being accessible by a jeepable road which branches off the Pokok Sena-Kg. Pdg. Sanai road.

As shown in Fig. 9, the proposed reservoir area is mostly covered by the farm of the Gula Padang Terap Sugarcane Plantation and the Syaricat Pintu Wang Melombong Sendirian Bdh. is mining at the northwest margin of the area. PWD is constructing a road across the area. The proposed reservoir area totally belongs to a forest reserve. FELDA has a plan to develop a rubber plantation in an area encompassing the whole proposed reservoir area. About 60% of the proposed reservoir area is classified as the possible mining land according to GSD.

Annual inflow from the catchment area of 61 km^2 is estimated to be 32 x 10^6 m^3. The active storage capacity of the reservoir of 56 x 10^6 m^3 in a drawdown of 22 m can regulate 23 x 10^6 m^3 of water if the normal HWL is assumed at El. 91 m.

The proposed dam is a concrete gravity dam of 47 m in maximum height and 170 m in crest length as shown in Fig. 15. The dam volume is 62,000 m^3. The crest is set at El. 95 m. A free overflow spillway of 71 m in effective width is located at the central section of the dam. A river outlet having 2 units of 1 m dia. outlet valves is installed in the spillway section. A diversion tunnel of 5.9 m in diameter and 165 m in length is located in the right abutment for the purpose of construction. A 270 m long saddle dam is constructed with embankment volume of 30,000 m^3 at 1 km to the southwest of the main dam.

The total investment cost is estimated to be M$72.5 x 10^6, including M$52.2 x 10^6 of cost for construction work and M$20.3 x 10^6 of land acquisition cost at 1982 constant price level.

5.4 The Durian Dam

The proposed Durian dam site is located in a wide valley of Juriassic to Jurassic sandstones, shales and siltstones with an alluvial flood terrace, just downstream of the confluence of the Durian Burong river and the Selaya river, tributaries of the Kedah river, being accessible by a jeepable road from Kg. Pdg. Sanai.

As shown in Fig. 10, the proposed reservoir area is totally covered by the farm of the Gula Padang Terap Sugarcane Plantation and its eastern part touches a forest reserve. FELDA has a plan to develop the northeastern part of the proposed reservoir area for rubber plantation. Mining potential is quite low.

Annual inflow from the catchment area of 74 km^2 is estimated to be 38 x 10^6 m^3. The active storage capacity of 41 x 10^6 m^3 in a drawdown of 14 m can regulate 21 x 10^6 m^3 of water, if the normal HWL is set at El. 74 m.

The proposed dam is a rockfill dam of 39 m in maximum height and 903 m in crest length as shown in Fig. 16. The crest is set at El. 79 m. The embankment volume is 1,084,000 m^3. A free overflow spillway of 48 m in effective width is located in the concrete gravity section on the saddle on the left abutment. Two lines of 4.7 m dia. diversion tunnels are excavated in the isolated hill. One of the tunnel is utilized for installing the river outlet having 2 units of 1 m dia. outlet valves.

The total investment cost is estimated to be M$113.3 x 10^6 including M$111.5 x 10^6 of the cost for construction work and M$1.8 x 10^6 of land acquisition cost at 1982 constant price level.

5.5 The Tawar-Muda Dam

The proposed Tawar-Muda dam consists of the main dam in the Muda river and the secondary dam in the Tawar river. Both sites belong to a Terrain of Triassic sandstones, shales and occasional lenticular intercalations of gritty sandstones and conglomerates, being located about 4.2 km upstream of the confluence of the two rivers. They are accessible by a jeep-able road from Nami.

As shown in Fig. 11, the proposed reservoir area is cultivated for rubber mini-estates of RISDA in its west and the rest is forest but partly belongs to the rubber plantation of FELCRA. An army camp and a part of Kg. Aur are located within the proposed reservoir area. The area belongs to a forest reserve in its northern part. The Veterinary Department has a plan to develop a cattle grazing land to the northeast of the proposed reservoir area. A small portion of the land duplicates the proposed reservoir. Mining potential is quite low.

Annual inflow from the catchment area of 129 km^2 between the Muda dam and the Tawar-Muda dam site is estimated to be 123 x 10^6 m^3. The active storage capacity of the reservoir of 54 x 10^6 m^3 in a drawdown of 11.5 m can regulate 41 x 10^6 m^3 of water, if the normal HWL is set at El. 77 m.

The proposed main dam is a rockfill dam of 34 m in maximum height and 338 m in crest length as shown in Fig. 17. The crest is set at El. 82 m. The embankment volume is 281,000 m^3. A free overflow spillway of 75 m in effective width is located in the concrete gravity section on the left of the dam. Two lines of 5.4 m dia. diversion tunnels are excavated in the right abutment. One of the tunnels is utilized to install a river outlet having 2 units of 1.5 m dia. outlet valves. Three saddle dams are constructed with total embankment volume of 43,000 m^3.

The proposed secondary dam is a rockfill dam of 31 m in height and 1,040 m in crest length as shown in Fig. 18. The crest is set at El. 77 m. The embankment volume is 870,000 m^3. A diversion tunnel of 3 m in diameter is excavated in the left abutment.

The total investment cost is estimated to be M$114.6 x 10^6 including M$103.8 x 10^6 of the cost of construction work and M$10.8 x 10^6 of land acquisition cost at 1982 constant price level.

5.6 The Beris Dam

The proposed Beris dam site is located in a narrow valley of Triassic sandstones, shales, gritty sandstones and conglomerates 1.6 km upstream of the confluence of the Muda river and the Beris river, being accessible by a foot-path from Kg. Kuala Beris.

As shown in Fig. 12, the proposed reservoir area is covered by forest reserve in its northwestern part and forest largely developed for rubber cultivation by small holders. The Nami-Sik road passes across the southeastern part of the proposed reservoir area, where Kg. Ternas and Kg. Sg. Batang are located. The Kedah Economic Development Authority is planning the Serai Wangi project of citronella in the northern part of the proposed reservoir area and the Forestry Department has a plan to grow teak, partly duplicating the proposed reservoir area. Mining potential is estimated to be low, though a mining prospecting has been applied for the northern part of the proposed reservoir area.

Annual inflow from the catchment area of 116 km^2 is estimated to be 110 x 10^6 m^3. The active storage capacity of the reservoir of 101 x 10^6 m^3 in a drawdown of 16 m can regulate 92 x 10^6 m^3 of water, if the normal HWL is set at El. 85 m.

The proposed dam is a concrete gravity dam of 42 m in height and 145 m in crest length as shown in Fig. 19. The crest is set at El. 89 m. The concrete volume is 58,000 m^3. A free overflow spillway of 72 m in effective width is placed and a river outlet with 2 units of 1.5 m dia. outlet valves is installed in the central section of the dam. A diversion tunnel of 5.6 m in diameter is excavated in the left abutment. A saddle dam of 150 m in crest length is constructed with embankment volume of 104,000 m^3, 0.5 km to the south of the main dam as shown in Fig. 20.

The total investment cost is estimated to be M$74.2 x 10^6 including M$45.2 x 10^6 of the cost of construction work and M$29.0 x 10^6 of land acquisition cost at 1982 constant price level.

5.7 The Rui Dam

The Rui dam is proposed in the Rui river, a tributary of the Perak river in order to regulate the river flow and divert it to the Tiak river, a tributary of the Muda river. The proposed reservoir area is located to the south of Kelian Intan which is located on the Keroh-Gerik road. A tunnel for basin transfer is excavated between an upstream portion of the reservoir area and the vicinity of Charok Pendiat which is located 14 km to the south of Baling. The Tiak power station is contemplated at the outlet of the tunnel.

The proposed reservoir area is situated in the geologic province of Silurian Baling Formation. Agrillaceous facies mainly comprising variegated shales, which is often phyllitic, is wide-spread in the dam and reservoir area. Lenticular beds of limestones are intercalated occasionally. The limestone is often crystalline, and its thickness varies from a few meters to several hundred meters. The limestone lenses are enlongated in the north-northeastly direction, but they are not continuous for more than 2 km in length.

Three dam sites, the Rui 1, 2 and 3, are investigated as mutually exclusive alternatives, but the Rui 1 is rejected because of significantly inferior foundation condition. The proposed Rui 2 dam site is located in a narrow valley at 4 km to the southwest of Kg. Pahit near a bridge on the Keroh-Gerik road and the proposed Rui 3 dam site is located 2 km downstream of the Rui 2 dam site.

As shown in Fig. 13, the proposed reservoir area is mostly covered by jungle, where there are Kg. Pong and Kg. Asu. The Rahman Hydraulic Tin Bhd. is operating the Tanah Hitam Mill to the northeast of the area. It has the Pong power station of 2 MW, a hydroelectric power station, in the southwest of the proposed reservoir area. The Rahman Hydraulic Tin Bhd. is considering to strengthen the Pong power station. Tin mining potential is high in the vicinity of the Tanah Hitam Mill and southwestern part of the proposed reservoir area. The tributary joining from the north to the Rui river between the Rui 2 and Rui 3 dam sites is utilized as the tailing area of the Tanah Hitam Mill, and it will be mostly flooded if the Rui 3 dam is constructed. GSD expressed in June 1983 that there is a possibility of uranium in the proposed reservoir area, but neither content nor volume is known.

It is proposed that river maintenance flow of 1.4 m^3/s should be continuously released into the Rui river, if the Rui dam is implemented. This discharge is more than sufficient for irrigation and other water uses in the Rui river system. Furthermore, no water deficit is expected in the Perak river.

There are the Kenering and Chenderoh power stations of NEB in the Perak river downstream of the confluence of the Perak river and Rui river. It is estimated that 20 GWh of energy will be lost at these power stations as a result of diversion of water from the Rui river to the Muda-Perai river system. The proposed Rui dam includes the construction of power supply network between NEB system and the proposed Rui power station annexed to the Rui dam and Tiak power station which is constructed at the outlet of the diversion tunnel. Energy produced at the Tiak power station is more than the above-mentioned energy loss and it is sent to NEB power supply network.

The above-mentioned new power supply system supplies 10 GWh of energy to the Tanah Hitam Mill and Intan Kelian township, in place of the Pong power station. For this purpose, the project should pay M$700,000 every year to purchase 5.6 GWh of energy from NEB and all the output of 4.4 GWh at the proposed Rui power station should be supplied free of charge.

(1) The Rui 2 dam

Annual inflow from the catchment area of 278 km^2 of the proposed Rui 2 dam is estimated to be 250 x 10^6 m^3. The active storage capacity of 245 x 10^6 m^3 in a drawdown of 42.5 m can regulate 214 x 10^6 m^3 of water if the normal HWL is set at El. 245 m. If 44 x 10^6 m^3 of water should be released downstream as the river maintenance flow, water available for basin transfer is 170 x 10^6 m^3.

The proposed dam is a rockfill dam of 77 m in maximum height and 460 m in crest length as shown in Fig. 21. The crest is set at El. 251 m. Embankment volume is 2,714,000 m^3. A side channel spillway of 117 m in the effective overflow crest length is located on the left side of the dam.

Two lines of 6.6 m dia. diversion tunnels are excavated in the right abutment. One of them is utilized for the installation of a 880 kW power station (the Rui power station) and outlet facilities with a 1.2 m dia. outlet valve. Annual energy output of the power station is estimated to be 4.4 GWh. All energy is sent to the Tanah Hitam Mill and Intan Kelian township free of charge.

The investment cost for the construction of the Rui 2 dam and the Rui power station is estimated to be M$392.0 x 10^6 including M$391.6 x 10^6 of the cost for construction work and M$0.4 x 10^6 of land acquisition cost at 1982 constant price level.

(2) The Rui 3 dam

Annual inflow from the catchment area of 305 km^2 of the proposed Rui 3 dam is estimated to be 273 x 10^6 m^3. The active storage capacity of 383 x 10^6 m^3 in a drawdown of 48.5 m can regulate 269 x 10^6 m^3 of water. Water available for basin transfer is 225 x 10^6 m^3, if the river maintenance flow downstream is 44 x 10^6 m^3.

The proposed dam is a rockfill dam of 85 m in maximum height and 300 m in crest length as shown in Fig. 22. The crest is set at El. 256 m. Embankment volume is 1,634,000 m^3. A side channel spillway of 126 m in the effective overflow crest length is located at the left end of the dam. Two lines of 6.9 m dia. diversion tunnels are excavated in the left abutment. One of them is utilized for the installation of a 500 kW power station (The Rui power station) and a 1.2 m dia. outlet valve. Annual energy output of the power station is estimated to be 4.4 GWh. All energy is sent to the Tanah Hitam Mill and Intan Kelian township.

The investment cost for the construction of the Rui 3 dam and the Rui power station is estimated to be M$405.6 x 10^6 including M$398.3 x 10^6 of the cost for construction work and M$7.3 x 10^6 of land acquisition cost at 1982 constant price level.

(3) The basin transfer facilities and Tiak power station

A 3.5 m dia. tunnel is constructed in a distance of 9 km between the confluence of the Rui river and the Pong river in the proposed reservoir area and a tributary of the Tiak river near Kg. Charok Pendiat as shown in Fig. 23. Rocks are shales for 3 - 4 km in the upstream portion and intruded granite in the downstream portion. It is probable that the tunnel intersects a few structural faults and many subordinate ones. It is also assumed that the tunnel is encountered by zones of hydrothermal alternation of deterioration in the shale bed. Granite is massive but deep weathering is apparent.

The Tiak power station is located at the foot of a hill slope of intruded granite 300 m to the north of Kg. Charok Pediant. A surge tank is constructed near the downstream end of the tunnel and the tunnel is connected with a penstock of 2.5 m in diameter and 220 m in length, leading to the power station. The installed capacity is 26 MW. The power station also houses 2 units of 1.2 m dia. outlet valves. Annual energy out-put is estimated to be 60 - 74 GWh.

The investment cost for the construction of the basin transfer facilities and Tiak power station is estimated to be M$167.7 x 10^6 at 1982 constant price level.

5.8 Summary Tables of Proposed Dams

The principal features of proposed dams are summarized in Tables 15 and 16, for the preliminarily determined size, and the corresponding land use under the present condition is tabulated in Tables 17 and 18.

5.9 Potential Dams

In addition to the existing, on-going and proposed source development projects, 4 potential projects, the Reman dam, Merbok storage, Ma dam and Khlong Thepha dam are incorporated in the Study. The principal features of these projects are summarized in Table 19.

(1) The Reman dam

The Reman dam is envisaged to add a pumped-storage reservoir of 240 x 10^6 m^3 in active storage capacity to the Jeniang system. Water is lifted from the civersion tunnel connecting the Jeniang weir and Naok dam into the Reman dam in the wet season and it is released in the dry season either into the diversion canal for the use in the MADA area or into the Muda river for the use downstream. According to DID Feasibility Study of Reman Reservoir Project Final Report, January 1984, by Minconsult & Nippon Koei, the Reman dam can contribute to the regional water demand and supply balance to a great deal with a low cost of water. No serious problem is expected from the technical point of view, but the State Government of Kedah has not decided to implement the Reman dam yet, because a rubber plantation project is going on in the proposed reservoir area.

(2) The Merbok storage

DID Feasibility Study for Proposed Jeniang Diversion, Naok Reservoir and Transfer Canal Draft Final Report, August 1983, by Syed Muhammad Hooidan Binnie & Renardet Engineering, indicated a possibility of a pumped-storage project called the Merbok storage. A reservoir of 13 km^2 in surface area is created by constructing an earth dyke in the coastal mangrove swamp on the left bank of the Merbok river. A canal is excavated between the reservoir and the pond of the Muda barrage. Water is pumped up from the Muda river into the reservoir through the canal between June and August for the release to the Muda river during the rest of the year.

(3) The Ma dam

The Ma dam site was identified by the Jeniang Team in the Ma river 8 km upstream of the confluence of the Muda river and the Ma river. It is located in the west of Kemajuan Tanah Lubok Merbau. Annual inflow from the catchment area of 40 km^2 is estimated to be 38 x 10^6 m^3. An active storage capacity of 35 x 10^6 m^3 can regulate 30 x 10^6 m^3 of water if a 50 m high dam is constructed. The construction cost is preliminarily estimated to be M$150 x 10^6.

(4) The Khlong Thepha dam

The Khlong Thepha dam site is identified through a study on 1/63,360 map. The dam site is located in Thailand 20 km to the northeast of the Pedu dam. Annual inflow from the catchment area of 173 km^2 is estimated to be 87 x 10^6 m^3. An active storage capacity of 78 x 10^6 m^3 between Els. 120 m and 125 m can regulate 73 x 10^6 m^3 of water, if a 50 m high dam is constructed. The reservoir area of 15.6 km^2 generally trending in the north-south direction stretches to the east in the upstream portion near the borderline between Malaysia and Thailand. A basin transfer canal of 6 km in length is excavated between this portion of the reservoir and the upper basin of the Pedu river, through a saddle having a crest at El. 150 m across the borderline.

6. WATER DEMAND AND SUPPLY BALANCE PLAN

6.1 Scope

This Chapter is devoted to the formulation and evaluation of water demand and supply balance plan for the Kedah-Muda-Perai river system, while no other source project is recommended for the Perlis river system than the on-going Timah-Tasoh dam, which is evaluated to be able to meet all the water demand including the river maintenance flow expected by 2000 in the Perlis river system.

The on-going Arau dam is not included in the analysis, because it is just enough to meet the water demand of the minor irrigation projects which will be newly implemented in the Arau river only and, accordingly, it will contribute neither positive nor negative impact on the regional water demand and supply balance except for a limited area.

It is assumed that the on-going Ahning dam, Jeniang system excluding the Reman dam, and Mengkuang dam will be commissioned by 1990. Any of the proposed dams except for the Rui dam are technically possible to be put in operation by 1991. No constraint is assumed for the implementation of these dams.

It was expressed in the Steering Committee meeting held in July, 1983 that the State Government of Perak could not make decision whether further study on the Rui dam be accepted or not, unless an investigation on the mining potential in the proposed reservoir area is performed. No program has been committed for the mining potential study in the area. The Rui dam is not assumed to be implemented in the near future.

The potential dams are not assumed to be ready for immediate implementation, because of unresolved social contraint or immaturity in investigaion.

Herein overall water demand and supply balance plan by means of the proposed dams except for the Rui dam is presented through an economic analysis. Then, possible overall plans including the potential source projects are described for higher safety in supply.

6.2 Basic Analysis of Economic Benefits and Costs

6.2.1 Net production value of paddy

The irrigation benefit is calculated as an incremental net production value between with and without project condition.

Without-project condition is assumed that all water demand and available water remain at the level in 1982. On the other hand, with-project condition is assumed that tertiary development in the MADA area and minor irrigation development are conducted and water demand increases as projected, while available water increases to the extent which is determined by the net water output of the source facilities assumed.

Under without-project condition, water is insufficient to a certain extent and there are the MADA area without tertiary development, minor irrigation projects, and rainfed land which can be provided with minor irrigation projects in the future.

Under with-project condition, it is assumed that there are the MADA area, minor irrigation projects which are implemented after 1982 and those which has been existing since 1982. In the MADA area, transplanting system is generally adopted in the main and off seasons, but direct-seeding system is applied for the off season cropping in certain areas. Part of the MADA area is not provided by tertiary development before 2000.

For the estimate of paddy production under with-project condition, it is, at first, assumed that water is sufficiently available and later on, the estimated net production value is adjusted to various levels of water availability.

(1) Crop yield

According to the paddy statistics, the paddy yield in 1981/82 is 4.0 ton/ha for the main season cropping and 4.2 ton/ha for the dry season cropping in the MADA area, 2.1 toh/ha for the rainfed cropping, 3.4 ton/ha for the main season cropping and 3.5 ton/ha for the dry season cropping in other paddy cultivation areas of the Region.

If such existing constraints as unstable supply of irrigation water, and insufficient tertiary canal system and farm road persist, increase in paddy yield cannot be expected. There has been no upward trend in paddy yield in the MADA area, where farming practices have already been developed. There is no incentive for farmers in other areas to increase paddy production. Consequently, the abovementioned paddy yield is assumed for the future under without-project condition.

If sufficient water is made available and the tertiary canal system and farm road system are improved, rice yield can be maximized under a reasonable cropping pattern which enables optimum application of fertilizer and water as well as adoption of suitable rice varieties to the regional climate.

It is assumed that the paddy yield in the MADA area is 4.7 ton/ha for the main season cropping, 5.0 toh/ha for the off season cropping on the transplanting fields and 4.8 ton/ha for the off season cropping on the direct-seeding fields under the condition that sufficient water is available and tertiary development is provided. For the minor irrigation projects which will be developed after 1982, paddy yield is assumed to be 4.2 ton/ha for the main season cropping and 4.8 ton/ha for the off season cropping under the condition that sufficient water is available and tertiary canal density is 45 m/ha.

Where the tertiary development is not provided yet in the MADA area, the crop yield is assumed to be equal to that under-without project condition but increased crop intensity is assumed. The existing minor irrigation projects, which are generally low in canal density, are assumed that no structural improvement is conducted, no more water is used than the present and, consequently, crop yield remains at the present level.

(2) Net production value

The economic farm gate price of paddy is estimated to be M$459/ton in 1982 and M$609/ton in 1995 constant price level, based on the actual price in 1982 and projected price for 1995 by IBRD for the standard 15% broken Thai grade, and assuming an average mill return of 65%. It is assumed that the farm gate price of paddy linearly increases between the above-mentioned prices from 1982 to 1995 and it is constant thereafter.

The net production value of paddy is estimated from the economic point of view, as the difference between the gross production value and production cost including family labor cost and fertilizer cost, which is estimated based on international market price. The net production value in 1995 onward at 1982 price level is estimated as shown in Table 20.

(3) Crop intensity

The schedule of double cropping a year in the MADA area is always staggered and the period of every two crops exceeds over one year. This has resulted in the cancel of one off season cropping every 6 years. The off season crop area is limited within 94% of total area. These facts are caused by insufficient water available. The average crop intensity of 178% at present is assumed for the MADA area under without-project condition. The cropping intensity in the existing minor irrigation projects has a wide range between 100% and 200% depending on water availability in individual project. It is 108% in the Kedah river basin and 176% in the Muda river basin on an average. It is assumed that the present cropping intensity is unchanged to the future, water being used within the present water right.

Under with-project condition, cropping intensity in the whole MADA area is assumed to be 197%. For the minor irrigation projects to be developed after 1982, cropping intensity is assumed to be 150% in a tributary, and 200% in the main stream.

(4) Total net production value

It is estimated that the scheduled cropping intensity is made possible as soon as sufficient water becomes available but paddy yield will be built up to the maximum in 4 years after that time. The net production value in the final year of tertiary development is assumed to be M$1,000/ha being affected by construction work.

The total net production value in 2003 onward under with- and without-project conditions is shown in Table 21. The values for with-project condition are estimated assuming that water is sufficient.

6.2.2 Domestic and industrial water supply benefit

The benefit which accrues from the water deficit supply for domestic and industrial water supply is estimated based on the least-costly alternative criteria.

Outflow from a proposed dam is released into a river course and taken by water supply systems in all assumed cases. The water supply systems assumed for a least-costly alternative is, therefore, identical to those assumed for a specified project, and, accordingly, the benefit attributable to the water at the outlet of the specified dam is measured as the cost of water at the outlet of the least-costly alternative dam.

The least-costly alternative dam is herein assumed to be the proposed dam which is ranked next to the specified dam in priority among the proposed dams.

The cost of water of each proposed dam is calculated to be the annual equivalent of the cost of dam divided by the annual net water output from the dam as an average under the hydrological condition between 1961 and 1980.

The average annual net water output of a given dam is determined depending on the frequency and volume of water deficit. It is in the order of active storage capacity in the Kedah river basin, where water deficit occurs every year. On the other hand, the average annual net water output is far less than the active storage capacity in the Muda-Perai river system, because water deficit occurs once in several years. Consequently, water supply benefit per unit volume of water is different between the Kedah river system and the Muda-Perai river system.

The cost of water by proposed dam is estimated assuming a discount rate of 8% as shown in Table 22, for the use as the unit domestic and industrial water supply benefit in the Kedah river system and Muda-Perai river system.

The unit domestic and industrial water supply benefit herein described is the unit value of water which is utilized to supply the water deficit in domestic and industrial water supply. It is different from the unit value of all water taken at an intake. For instance, assume that an intake of unit volume of water is constructed in a stream where normally water is sufficient but there is no runoff in a month of the year. If the water deficit in the dry month is supplied with water which has a value of x. The unit value of all water at the intake is x/12.

6.2.3 Benefit under insufficient water supply

In estimating rice yield under insufficient irrigation, it is normally assumed that the crop area is reduced in proportion to water available, as the relationship between water applied on an area and rice yield on the area has not been quantified. The seasonal variation in water deficit can be considerably adjusted by applying a reasonable operation rule of reservoir. The above-mentioned assumption can, therefore, be justified in the Region. Consequently, it is assumed that the net production value in an area reduces in proportion to water deficit.

For the domestic and industrial water supply under insufficient supply, the unit benefit is uniformly applied to the incremental supply of water deficit.

6.2.4 Economic cost of source facilities

The economic investment cost of the proposed dams is assumed to be 80% of the corresponding financial investment cost except for the compensation cost for agricultural land, assuming that the remaining 20% is the transfer payment.

The production and utility except the agricultural land can be continued at the same level as previously conducted on substitutional lands which are non-productive as present, if the land acquisition cost is appropriately invested. In other words, the implementation of a proposed project causes an investment for land acquisition, but it causes no change in production and utility. The substitutional land for agricultural use should hold a production potential and, therefore, it is already cast in an agricultural development program, which is implemented irrespective of the proposed project. Compensation cost on agricultural land is not an additional cost and the production in the previous land is forgone. Consequently, the compensation cost on agricultural land is not included in the economic investment cost but the agricultural production forgone is counted as an annual economic cost. If the Rui dam is implemented, lost energy at the Pong, Kenering and Chenderoh power stations should also be counted as a production forgone.

The estimated economic investment cost and annual cost, including O&M cost and production forgone, are shown in Table 23, for the proposed and potential dams and the Jeniang transfer, of which costs are borrowed from DID Feasibility Study for Proposed Jeniang Diversion, Naok Reservoir and Transfer Canal, Draft Final Report, Aug. 1983.

6.2.5 Economic cost of irrigation facilities

The financial investment cost of irrigation facilities are estimated to be M$9,000/ha for the tertiary development for the MADA area, M$11,500/ha for pump/gravity schemes and M$9,000/ha for control head offtake schemes. The economic investment cost is assumed to be 80% of the financial cost.

6.2.6 Recreation benefit

The present value of reservoir recreation benefit is estimated to be M$9.3 x 10^6 for the Jeniang system, M$13.9 x 10^6 for the Beris dam and M$13.2 x 10^6 for the Tawar-Muda dam, assuming a discount rate of 8%. This is measured with the fuel cost for travelling to the reservoir by domestic visitors as willingness-to-pay.

This benefit is not counted in the present study, only for the purpose of simplifying the analysis.

6.3 Overall Source Development Plan

6.3.1 Operation rule of source projects

The purpose of source development is to supply the water deficit with surplus water which otherwise runs to the sea unused. Normally the surplus water is found in the wet season but the water deficit takes place in the dry season. A dam is constructed to retain surplus water in the wet season for the water deficit supply in the dry season. In the Kedah river system, a large water deficit takes place even in the wet season and the surplus water appears only occasionally at the events of flood. Surplus water diverted from the Muda-Perai river system by the Jeniang system is conveyed into the Naok dam. It is immediately released to supply the wet season water deficit in the Kedah river system except that 27×10^6 m^3 is retained in the Naok dam for the use in next dry season.

The Beris and Tawar-Muda dams to be located upstream of the Jeniang weir, are cycle regulation dams. They fill up their reservoir by retaining surplus water in the Muda-Perai river system when the wet season comes. The dams release water into their downstream river course in the dry season in order to supply water deficit in the Kedah river system and/or the Muda-Perai river system.

The Jeniang system should be operated to meet the water demand in the southern half of the MADA area as much as possible, so that supply by the Pedu dam to the remaining area can be increased.

All the existing and assumed dams in the Kedah-Muda-Perai river system share all the water deficit which is remaining after the supply by the Jeniang system in proportion to an average net water output. If a dam uses up its active storage, its water output is adjusted to inflow, until the inflow reaches the water output assigned to the dam.

The operation of the Jeniang weir should neither cause or increase water deficit in the Muda-Perai river system nor reduce river flow immediately downstream of the weir below a certain rate, which is herein assumed to be the minimum recorded runoff of 2 m^3/s between 1961 and 1980. In relation to the allocation of water between the water users in the Kedah river system and those in the Muda-Perai river system, 3 alternative operation rules of the Jeniang system are assumed:

Alternative 1: Assuming the priority on the existing and future water users in the Muda-Perai river basin, the Jeniang weir is allowed to take water, only if it does not lower the water level upstream of the Muda barrage.

Alternative 2: As a compromise, water deficit is allocated to the Kedah river system and Muda-Perai river system in the proportion to the total water demand, by setting the ceiling discharge over the Jeniang weir.

Alternative 3: Assuming the priority on the Kedah river, the Jeniang weir is permitted to take water unless it does not interfer the presently existing water users in the Muda-Perai river system, but the river maintenance flow should be sustained. For this purpose, a ceiling discharge is set smaller than that for Alternative 2.

The operation of the Jeniang system according to Alternative 1 is assumed throughout the Main Report, but necessary detailes are compiled in ANNEXes I and N not only for Alternative 1 but also Alternatives 2 and 3.

6.3.2 Economic optimization

An economic optimization is made on the overall water demand and supply balance plan which integrates the projected irrigation development and domestic and industrial demand, based on the net benefit maximization criteria.

Source projects incorporated in the plan formulation are the on-going and proposed projects except for the Rui dam, but the Rui dam and the potential dams are not taken into account because of uncertainty of their implementation.

It is assumed that water demand increases as projected in Chapter 4 and direct facilities for individual purposes are accordingly developed, irrespective of the progress of source development. If the scale of source development is small, water deficit remains and accordingly benefit is small. If the scale of source development is increased by an additional cost, benefit increases. If the incremental benefit is larger than the incremental cost, the scale of development should be further increased, according to the net benefit maximization criteria.

The priority among the proposed dams except for the Rui dam is assumed in the order of the Beris, Tawar-Muda, Sari, Badak-Temin and Durian, according to the reverse order of the investment cost/net water output as shown in Table 24.

The smallest source development plan involves the Jeniang system only, in addition to the other on-going source project. The next smallest is the Jeniang system + the Beris dam, followed by the Jeniang system + the Beris dam + the Tawar-Muda dam, and so on.

The benefit and cost of the Ahning dam and Mengkuang dam are excluded from the analysis.

The economic benefits counted are the incremental net production value in the Muda irrigation project and minor irrigation projects, and the domestic and industrial water supply benefit in terms of water deficit supply. The costs are those for the source development projects, the tertiary development for the MADA area and minor irrigation development.

The estimated present value of net benefit, or benefit less cost; (B-C) is plotted against the present value of cost in Fig. 24 for varying discount rate. On the line connecting the alternative plans for a fixed discount rate, the plan corresponding to the largest value of net benefit is the optimum from the economic point of view.

At a discount rate of 8%, the value of net benefit increases till the Tawar-Muda dam is added, but it reduces if the Sari dam comes in. In other words, the Beris and Tawar-Muda dams should be developed in addition to the on-going source projects, if the opportunity cost of capital is set to be 8%.

Alternative 1 defined in Sub-Section 6.3.1 is assumed for the operation of the Jeniang system in the above description. The same calculation results assuming Alternative 2 and 3 are compiled in ANNEX N.

The value of net benefit is a little smaller in Alternatives 2 and 3 than that in Alternative 1, implying that best economy can be attained if the priority is put on the Muda-Perai river system in operation of the Jeniang system. If the priority is shifted from the Muda-Perai river to the Kedah river to a certain extent, the optimum plan reduces to the implementation of the Beris dam only in addition to the on-going source project.