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No. 1

MALAYSIA

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY, MALAYSIA
PERLIS-KEDAH-PULAU PINANG
REGIONAL WATER RESOURCES STUDY
PART 2
BERIS DAM FEASIBILITY STUDY

VOL. 1
MAIN REPORT

MARCH 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

NATIONAL WATER RESOURCES STUDY, MALAYSIA

PERLIS-KEDAH-PULAU PINANG

REGIONAL WATER RESOURCES STUDY

PART 2

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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 2 Feasibility Study on Beris Dam to the Government of Malaysia.

This report embodies the result of a multidisciplinary survey of water resources in P.K.P. Region and of the feasibility of the Beris Dam, which was carried out from December 1983 to March 1985 by a Japanese survey team commissioned by the Japan International Cooperation Agency following the request of the Government of Malaysia to the Government of Japan.

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

I hope that this report will be useful as a basic reference for development of the Project and contribute to the promotion of friendly relations between our two countries.

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

March 1985

Keisuke Arita
President
Japan International
Cooperation Agency

JAPAN INTERNATIONAL COOPERATION AGENCY

NATIONAL WATER RESOURCES STUDY, MALAYSIA
PERLIS-KEDAH-PULAU PINANG
REGIONAL WATER RESOURCES STUDY
PART 2
BERIS DAM FEASIBILITY STUDY

March 1985

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 2, Beris Dam Feasibility Study, 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.

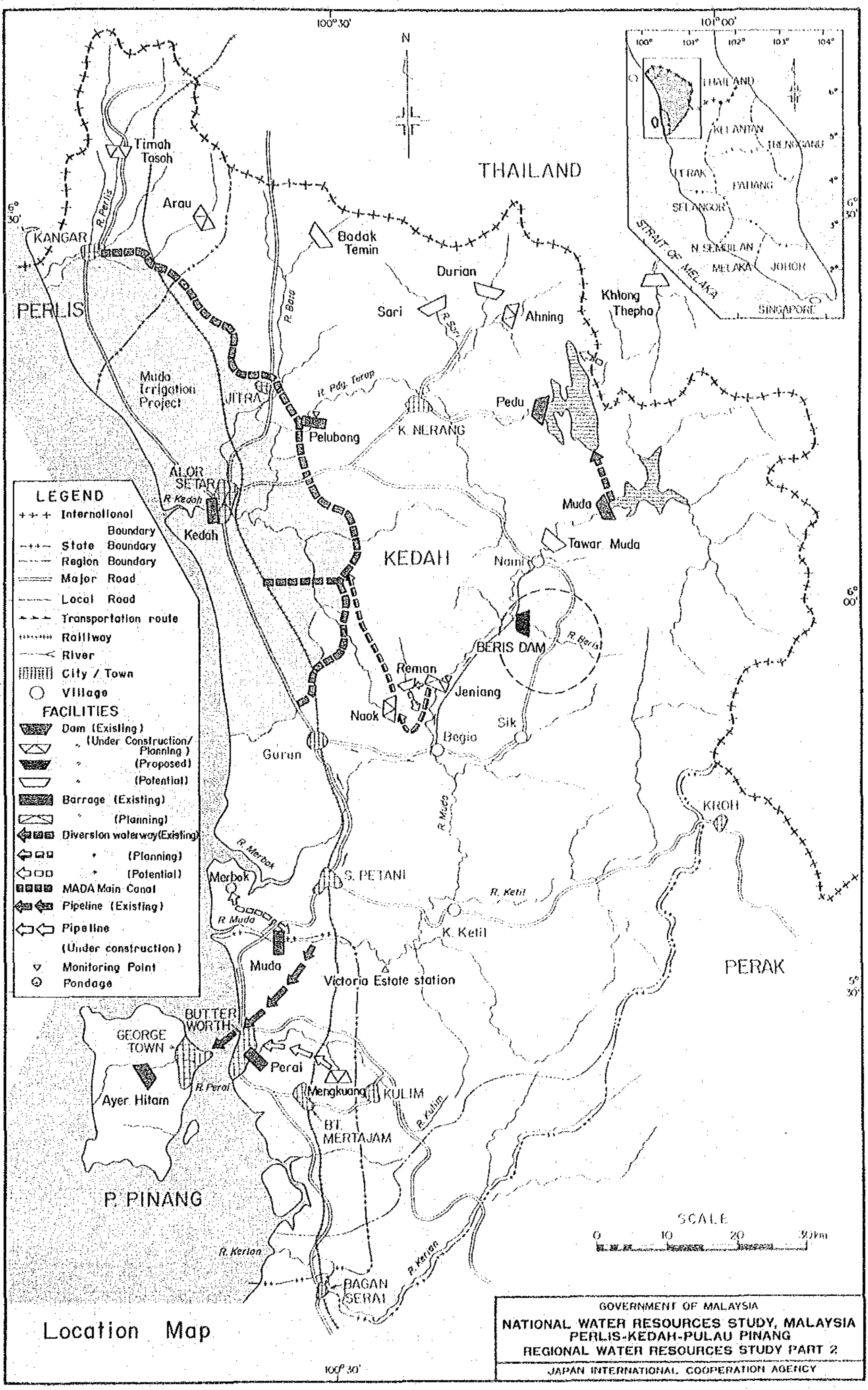
This report includes a preliminary design, cost estimate, and evaluation of the proposed Beris dam project which will contribute significantly to improving the balance between regional water demand and supply.

Another important study included in this report concerns the allocation of water between the various water users in the States of Perlis, Kedah, and Pulau Pinang. A reasonable priority concept and integrated operation rule of the existing and proposed water resources projects were studied for effective use of water resources, because they are specially required in such a water-stress region as the specified.

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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Muda Irrigation Project
JITRA
R. Pdg. Terap
Pelubang
K. NERANG
Pedu
ALOR SETAR
R. Kedah
Kedah
Muda
Tawar Muda
KEDAH
Nami
BERIS DAM
R. Beris
Reman
Jeniang
Naok
Sik
Begia
Gurun
R. Muda
KROH
R. Merbok
Merbok
S. PETANI
R. Ketil
K. Ketil
R. Muda
Muda
Victoria Estate station
PERAK
BUTTER WORTH
GEORGE TOWN
Perai
Ayer Hitam
R. Perai
Mengkuang
KULIM
R. Kulim
BT. MERTAJAM
P. PINANG
R. Kerian
BAGAN SERAI
R. Kerian
SCALE
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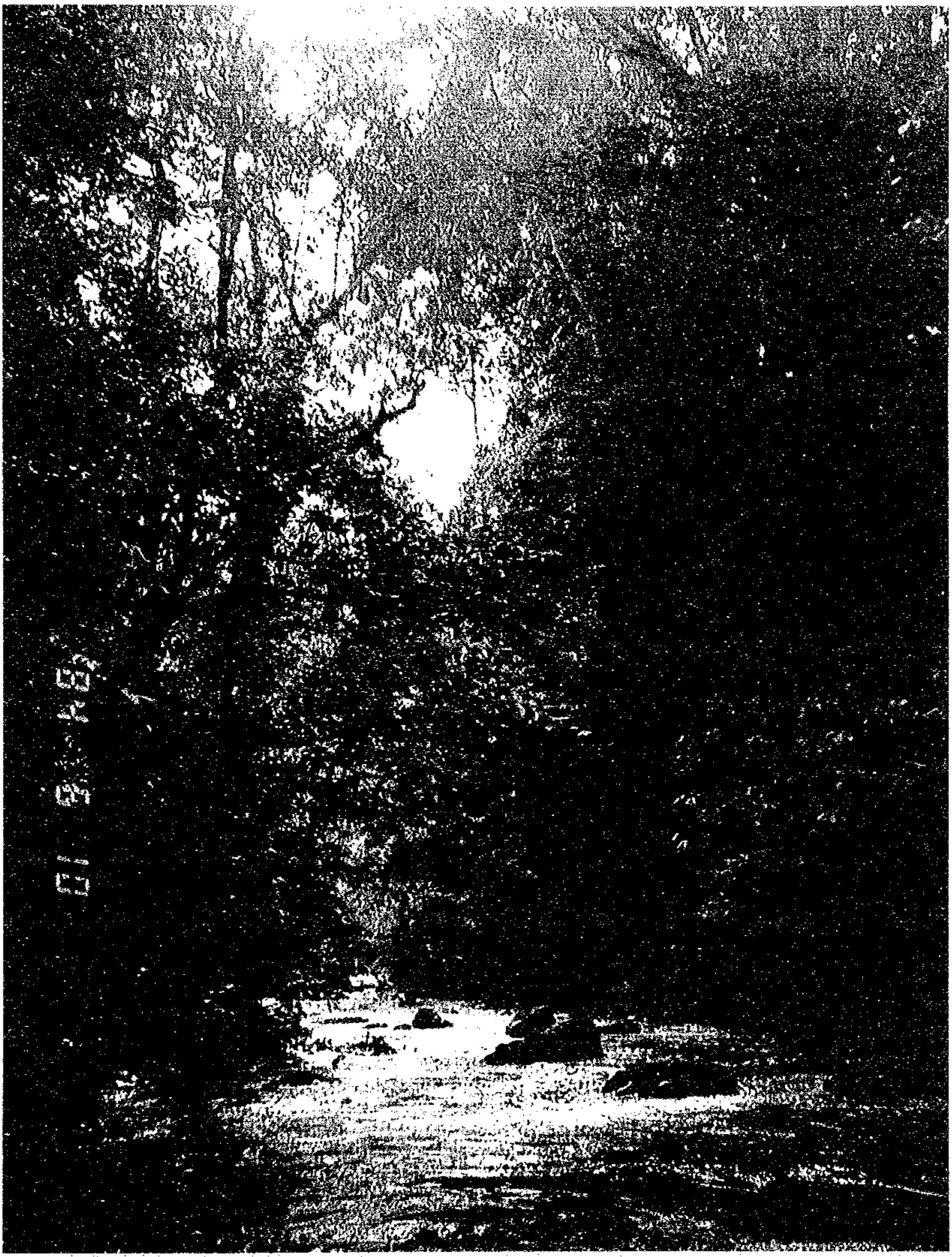
LEGEND
International Boundary
State Boundary
Region Boundary
Major Road
Local Road
Transportation route
Railway
River
City / Town
Village
FACILITIES
Dam (Existing)
(Under Construction/ Planning)
(Proposed)
(Potential)
Barrage (Existing)
(Planning)
Diversion waterway (Existing)
(Planning)
(Potential)
MADA Main Canal
Pipeline (Existing)
Pipeline (Under construction)
Monitoring Point
Pondage
Location Map
GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY, MALAYSIA
PERLIS-KEDAH-PULAU PINANG
REGIONAL WATER RESOURCES STUDY PART 2
JAPAN INTERNATIONAL COOPERATION AGENCY



Beris River at the Proposed Main Damsite

PRINCIPAL FEATURE OF PROPOSED BERIS DAM

1. River System	: Muda river
2. Reservoir	
Catchment area	: 116 km^2
Annual inflow (average)	: 109.4 x $10^6 m^3$
Maximum WL (FWL)	: El. 87.7 m
Normal HWL	: El. 85.0 m
LWL	: El. 69.0 m
Surface area at FWL	: 1,600 ha
Effective storage capacity	: 102.4 x $10^6 m^3$
3. Main Dam	
Type	: Concrete gravity
Crest elevation	: El. 89.0 m
Maximum height	: 41 m
Crest length	: 150 m
Dam concrete volume	: 55.2 x $10^3 m^3$
4. Saddle Dam	
Number	: 1
Type	: Rockfill (center core)
Crest elevation	: El. 90.5 m
Maximum height	: 28 m
Crest length	: 160 m
Embankment volume	: 121.6 x $10^3 m^3$
5. Spillway	
Discharge capacity	: 200 m^3/s
Overflow crest length (effective)	: 20 m
Crest elevation of overflow weir	: El. 85.0 m
6. River Outlet Facilities	
Main device	: Hollow Jet Valve 2 units
Discharge capacity	: 0.2 m^3/s - 15 m^3/s
7. Investment Cost at the end of 1983 Price Level	: M$96.6 x 10^6

SUMMARY

1. Study Objective

The Perlis-Kedah-Pulau Pinang Regional Water Resources Study (the Study) has been carried out based on the Scope of Work, which 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 overall objective of the Study was to formulate an integrated water resources development and management plan for the Perlis-Kedah-Pulau Pinang Region (the Region), to enable decisions to be made by the federal and state governments for implementation of water resources development projects. The Study was phased out as follows:

Part 1-(December 1982 to February 1984) to formulate a long-term master plan for water demand and supply balance, flood mitigation and water pollution abatement. This study resulted in a recommendation that the proposed Beris dam should be implemented by 1991 in order to meet immediate and future water demand in the Region.

Part 2-(December 1983 to March 1985) to study the feasibility of the Beris dam, and more specific ally (1) to make recommendations on water allocation and an integrated operation plan for the existing and proposed facilities; (2) to prepare a preliminary design and cost estimate of the Beris dam project; (3) to evaluate the Beris dam project from the economic, financial, social and environmental points of view; and (4) to make recommendations on implementation of the Beris dam project.

2. Main Conclusions of Part 1 Study

The Region roughly corresponds to the States of Perlis, Kedah and Pulau Pinang.

There is a large water deficit every year in the Kedah river system, even though the Pedu and Muda dams can regulate runoff to a great extent. There is no water deficit in the Muda-Perai river system, however, except in an occasional dry year. The existing Pedu and Muda dams, and Jeniang system and Ahning dam, planned or under construction, all aim to balance water demand and supply in the Kedah river system, but they cannot meet the whole water deficit without the implementation of the proposed Beris dam.

These rivers often overflow their banks, because of their small channel capacity, but flood damage is not an annual event. Flood mitigation works such as channel improvement, bypass floodway and flood retention storage are recommended to protect the main affected areas of Kangar, Kuala Nerang, Kuala Ketil, Butterworth and Georgetown.

Future increased water use will cause deterioration river water quality, though at present water pollution is found only in limited stretches of the river. As scheduled by DOE, all the rubber factories, palm oil mills and sugar mills using large amount of water should be required to install adequate treatment facilities for their effluents and sewerage system should be provided in Kangar, Alor Setar, Sg. Petani and Kulim, in addition to the ongoing development of sewerage systems in Butterworth and Georgetown.

From the viewpoint of water demand and supply balance all main rivers in the Region will constitute a single system spanning the States of Perlis, Kedah and Pulau Pinang, if the Jeniang system is implemented. A master agreement should be made between the Federal Government and the Governments of the three States, to provide for (1) a regional water resources master plan to be formulated and recognized, (2) allocation of water to each State, (3) integrated operation of all source facilities in the Region, (4) equitable allocation of the costs of water source facilities, and (5) the Federal Government to assist the states in the arbitration of disputes, if any, at the request of any one of the three States.

3. Updating of Water Demand Projection

The socio-economic projections made in Part 1 Study were updated, in accordance with the Mid-Term Review (MTR) of the Fourth Malaysia Plan (4MP), which adjusted estimates of population and gross domestic product (GDP) downward. The updated population estimate was slightly smaller than the previous projection. GDP in 2000 was adjusted from M$15.9 x 10^9 to M$13.4 x 10^9, assuming a growth rate of 6.7% for 1980 - 1985, 7.5% for 1985 - 1990, 7% for 1990 - 1995 and 6.5% for 1995 - 2000.

Domestic and industrial water demand was recalculated according to the updated socio-economic data, assuming that the service factor in 2000 is 100% for domestic water supply and 90% for industrial water supply. Domestic and industrial water demand in 2000 in the Region was estimated to be 560 x $10^6 m^3$, which is 21% less than the previous estimate of 709 x $10^6 m^3$.

Minor irrigation schemes of 5,604 ha including fringe areas of 2,457 ha have been identified by Kedah DID and were assumed to be implemented by 1990 in Part 1 Study. The development of new fringe areas was totally omitted in the projection in Part 2 Study according to the policy recently expressed by Kedah State Authorities. According to the results of the tertiary development to date, the reduction in the irrigation area due to the land acquisition for the tertiary facilities was assumed to be 4% of the original irrigation area. Based on comments and opinions expressed in a workshop which was held on July 9, 1984 at MADA headquarters, some modifications were made in the irrigation method in the MADA and fringe areas. With these modifications in assumptions the irrigation water demand in 2000 in the Region was estimated to be 1,959 x $10^6 m^3$, or 13% less than the previous estimate of 2,246 x $10^6 m^3$.

4. Water Deficit

The water deficit was calculated from the hydrological records between 1961 to 1983, assuming that the Pedu-Muda dam system and Ayer Hitam dam are in existance and that the Ahning dam and Mengkuang dam are completed before 1990.

The average annual water deficit in the main stream of the Kedah river was estimated to be 409 x $10^6 m^3$ in 1983 and 399 x $10^6 m^3$ in 2000, while in the Muda-Perai river it was estimated to be 7 x $10^6 m^3$ in 1983 and 23 x $10^6 m^3$ in 2000.

The causes of the water deficit were analysed on assumption that; the water deficit in 1983 is caused by the existing water users in proportion to their water demand; and in future years the incremental water deficit will be allocated to water users in proportion to their incremental water demand after 1983. The water deficit allocated to the causes may be summarized as follows:

Summary of Water Demand and Deficits 1983/2000

Unit: $10^6 m^3$

	1983		2000		
	Demand	Deficit	Demand	Deficit	Difference
Kedah river	1364		1421		
MADA		390		340	-50
Minor irrigation		14		29	+15
D&I water supply		5		16	+11
Maintenance flow		-		14	+14
Total		409		399	-10
Muda-Perai river	314		495		
Kedah State:					
Minor irrigation		2		13	+11
D&I water supply		-		2	+2
Pulau Pinang State:					
Minor irrigation		4		3	-1
D&I water supply		1		5	+4
Total		7		23	+16

5. Policy for Water Demand and Supply Balance

A water demand and supply balance plan should be formulated based on a target of safe supply, which is expressed by some parameters representing the risk of safe supply. Referring to design criteria in Malaysia, the target is herein assumed, for the hydrological condition of the 23-year period between 1961 and 1983, as follows:

> For domestic and industrial water supply, safe supply should be guaranteed even under the driest condition. For irrigation, (1) number of deficit year should not be more than 5, (2) percentage of average annual water deficit to average annual water demand should not be more than 1%, and (3) the greatest percentage of water deficit in a month to water demand in the same month should not be more than 50%.

Furthermore, it was recommended that the following priority order to take river water be set among water users in the Region:

(1) Domestic and industrial water use should be given inviolable priority.

(2) Minor irrigation projects should be given priority over those depending on the main streams.

(3) All irrigation projects in the upstream and downstream reaches of the main stream should be given equal priority.

(4) An existing project should have priority over a new project, in principle, but for the time being, the existing and new projects should be given equal priority, because new projects have to be implemented though water deficit already takes place in existing projects.

6. Output of the Jeniang System and Beris Dam

Surplus water in the Muda river would be transferred by the planned Jeniang System to the Kedah river system, and there are large water demand centers in the downstream reaches of the Muda river. The Beris damsite is located upstream of the Jeniang barrage. The allocation of output of the Beris dam to the Kedah river system and Muda-Perai river system would be determined by the operation rule adopted for the Jeniang system. Three alternative operation rules of the system are proposed; Alternative 1 (Muda priority): Water may be diverted to the Kedah river, only if it does not cause a water deficit in the Muda river, Alternative 2 (Even distribution): Downstream release is limited to 15 m^3/s, so that the target risk of safe supply would be attained in the two river systems, and Alternative 3 (Kedah priority): Downstream release limited to 2.5 m^3/s, so that present and future water deficit in the Muda-Perai river basin will be approximately equal to what would occur without the Jeniang system.

The average annual deficit in the Kedah river system with the Jeniang system was estimated to be 182 x $10^6 m^3$ in 1990 and 185 - 187 x $10^6 m^3$ by 2000. The annual supply capacity of the system will be almost the same with any of the alternative rules. The average annual output of the Beris dam is estimated to be 62 - 66 x $10^6 m^3$, which would leave a remaining water deficit with the Jeniang system and Beris dam of 114 - 117 x $10^6 m^3$ in 1990 and 145 x $10^6 m^3$ in 2000.

7. Recommended Alternative

If Alternative 1 is taken up as the operation rule of the Jeninag system, no water deficit will take place in the Muda river except in an extraordinary dry year. On the other hand, the irrigation projects in the State of Kedah will be operated under different risks of safe supply between the two river basins.

In Alternative 2, equal priority was assumed to the Kedah and Muda river basins and the target risk of safe supply would be attained in the two river basins.

Alternative 3 cannot meet the assumed target for safe supply in the Muda river and therefore is not recommendable.

Although there is no decisive factor for the selection between Alternatives 1 and 2, Alternative 2 is recommended only from the viewpoint of equality in the Region. It was proved that these Alternatives were also economically satisfactory, having the same order of EIRR as described later.

8. Operation Rule and Monitoring System

For management of the water resources facilities in the integrated river system, it is recommended that a control center be established to issure operational instructions to all the source facilities including the Pedu, Muda, Ahning and Beris dams, and the Pelubang, Jeniang, Kedah and Muda barrages. The center should also operate monitoring stations at the Pelubang barrage, Jeniang barrage and Victoria Estate hydrological station.

The outflow from each dam should be determined at intervals of several days based on the scheduled water demand in a time interval and natural flow estimated from the discharge recorded in the antecedent time interval at the monitoring stations.

The critical period will be between February and June corresponding to the off-season crop period. The off-season crop area should be decided at the beginning of February and adjusted at the beginning of April based on available water in the Pedu and Muda dams. Furthermore, water rationing should be conducted if the water level in the Pedu reservoir falls to a pre-determined elevation. The Ahning dam and Beris dam should be operated to supply water during the above-mentioned critical period.

9. Proposed Damsite and Reservoir Area

The proposed Beris damsite is located in the narrow valley of the Beris river, 1.6 km upstream of its confluence with the Muda river. The riverbed is at El. 50 m. The reservoir area would extend into the hilly region to the southeast of the damsite. The upstream area has a mildly undulating terrain with low relief.

The proposed damsite and reservoir area are situated in the geological province of the Triassic Semanggol Formation of sandstones, shales, gritty sandstones and conglomerates. Instrusive granite is encountered at the upstream end of the reservoir area.

The river channel, 20 m in width, adjoins mountain slopes of 30° on both banks of the damsite. It frequently exposes bedrocks such as gritty sandstones and conglomerate, while the river deposits are shallow and at a steep slope of about 1/100. There are no signs of faulting. A saddle damsite would be required about 700 m to the northeast of the main damsite. The lowest ground of the saddle is at El. 70 m. The topography at this site is gentle, with an overburden 4 m to 10 m in depth. Faults perpendicular to the dam axis were inferred at the middle and at the right side of the proposed site.

The present land use in the proposed reservoir area of 1,597 ha includes 492 ha of rubber plantations, 143 ha of paddy fields, 261 ha of residential and mixed cultivation areas, 561 ha of unalienated forest and 140 ha of alienated forest. Out of 510 houses in Kg. Batu Seketul, Kg. Sg. Batang and Kg. Terenas, 336 houses and a 4.2 km stretch of the Nami-Sik road are located in the area.

10. Proposed Facilities

The main components of the proposed Beris dam will be the division facilities, main dam, spillway, outlet works, saddle dam and relocated road.

The river at the damsite would be diverted through a diversion tunnel, and the dam foundation would be kept dry by being protected from flooding by upstream and downstream cofferdams, in order to carry out the construction work of the main dam under a dry condition. A diversion tunnel of 215 m in length and 1/54 in slope would be driven through the right abutment of the main dam. It will require a concrete lined horseshoe shaped cross section 5 m in diameter with a capacity of 200 m^3/s. The permanent closure would be by a concrete plug system after closure of the tunnel by stop logs. The upstream cofferdam would be a concrete gravity dam and the downstream cofferdam a random fill dam.

The main dam would be a concrete gravity dam of 41 m in the maximum height, 150 m in crest length and 55 x 10^3m^3 in volume. The crest elevation of the dam is set at El. 89 m, which allows wave height above the maximum water surface.

The reservoir maximum flood water level would be El. 87.7 m. The normal high water level would be El. 85 m and the low water level El. 69 m. The active storage capacity would be 102.4 x 10^6m^3.

A spillway would be provided to release surplus water which cannot be contained in the reservoir. It would be designed to secure safety against the probable maximum flood. The spillway would be located in the centre of the main dam with a non-gated ogee crest at El. 85 m. The downstream face of the dam would be utilized as the chuteway with a concrete lined horizontal apron type energy dissipator at the foot of the dam. The width of the spillway would be 20 m, being limited by the width of the valley.

Outlet works would be provided in the main dam, to release water from the reservoir to the river course downstream at varying rates between 0.2 m^3/s and 15 m^3/s as required by downstream water users. The outlet works would consist of two sets of facilities each capable of 15 m^3/s, and each set comprising an intake on the upstream face of dam, a steel penstock embedded in the dam body, a guard valve and a hollow jet valve 1.5 m in diameter, and a high pressure slide gate valve of 0.6 m in diameter. The intake will have a temporary low level opening to release a minimum discharge during the initial filling of the reservoir.

The proposed saddle dam would be a zoned rockfill dam with a central earth core 28 m in maximum height, 160 m in crest length and 121.6 x $10^3 m^3$ in volume. The crest elevation of the dam would be at El. 90.5 m. The upstream slope would be 1:2.3 and downstream slope is 1:1.8 with a crest width of 8 m.

A new 12 km long road would be constructed to relocate the flooded section of the Nami-Sik road with an effective width of 5.5 m. It would include a 300 m long bridge over a narrow section of the reservoir.

A small scale hydropower development would be possible for the Beris dam project by utilizing potential of outflow discharge when the reservoir would be operated to meet the downstream water demand. The power station would be able to be operated approximately for 7 months a year and the annual energy output of the power station was estimated to be 4.05 GWh on average with an installed capacity of 3,000 kW. The net present value of incremental (B-C) in case of the power station being added was, however, calculated to be negative at the interest rate of 8%. The hydropower development at the Beris dam is not economically justified.

11. Construction Schedule and Cost

It is estimated that it will take 21 months for pre-construction work, 31 months for construction and 12 months for the initial filling of the reservoir. Assuming that the Beris dam should be commissioned at the beginning of the Sixth Malaysia Plan (6MP) period, the construction work should be carried out between June 1987 and December 1989.

The construction cost of the Beris dam is estimated to be M$96,590,000 comprising M$20,450,000 of foreign currency and M$76,140,000 of local currency, including allowance for price escalation at a rate of 5% per annum for both foreign and local currency portions as summarized below:

BREAKDOWN OF CONSTRUCTION COST

Unit: M$$10^3$

Item	Foreign Component	Local Component	Total
1. River Diversion Works	790	1,360	2,150
2. Main Dam	1,800	8,200	10,000
3. Stilling Basin	90	620	710
4. River Outlet	1,200	200	1,400
5. Saddle Dam	1,100	3,270	4,370
6. Relocation Road	1,520	5,710	7,230
7. Preparatory Works	1,000	3,040	4,040
8. Compensation	-	25,700	25,700
9. Engineering Services and Government Administration (Design and Supervision)	5,900	2,500	8,400
10. Contingencies			
Physical contingencies	2,680	10,120	12,800
Price escalation	4,370	15,420	19,790
Sub-total	7,050	25,540	32,590
Grand Total	20,450	76,140	96,590

12. Land Acquisition and Resettlement

Land acquisition costs would consist of compensation costs and relocation costs of public facilities in the proposed reservoir area. The compensation costs would include those on the agricultural land, forest alienated to private persons and displacement of families. The public facilities to be relocated would include part of the Nami-Sik road, a low voltage power line, a mosque, a school, a surau, a cemetery, a hospital and other public buildings. Among them the relocation costs of the Nami-Sik road and low voltage power line are herein excluded from the land acquisition cost and included in the direct construction cost. The land acquisition costs are estimated to be M$25.7 x 10^6 based on the present market prices and information provided by the Kedah Economic Development Authority (KEDA).

A resettlement plan has been worked out for reference. Under the condition that a detailed socio-economic survey is still to be conducted, it was assumed that new land should be developed and provided to allow the same land use as enjoyed at present in the proposed reservoir area. It shuold be noted that the resettlement plan in this Study is preliminary and a definitive resettlement plan should be prepared on the basis of the results of the detailed socio-economic survey to be carried out before the detailed design stage.

The proposed resettlement area for residential/ mixed cultivation area and paddy fields is located to the east of the Nami-Sik road about 3 km to the northeast of Kg. Batu Seketul. The present land use comprises 100 ha of forest reserve and 300 ha of rubber plantation. The mosque and other public facilities would be relocated here also. There is also a proposal to develop 500 ha of rubber plantation in the forest reserve along the proposed relocation road and on the western side of the existing Nami-Sik road near the proposed resettlement areas. The whole of Kg. Sg. Batang and the submerged part of Kg. Batu Seketul would be resettled in this area, but no resettlement plan has been proposed for Kg. Terenas, of which the submerged part it is assumed would be absorbed into the remaining part of Kg. Terenas. The cost of this resettlement is estimated to be M$18.5 x 10^6. If compensation for the removal of Kg. Terenas is added to this amount, the total cost would be approximately equal to the land acquisition cost as mentioned above.

13. Economic Analysis

The benefits and costs of the project have been estimated at the price levels at the end of 1983 and the evaluation period has been taken as 50 years starting from the beginning of 1984.

In estimating irrigation benefits, it has been assumed that all water demand and available water remain at the level of 1983 under the without-project condition. On the other hand, under the with-project condition, it is assumed that there will be tertiary development in the MADA area and other minor irrigation development and that the water demand will increase as projected. The economic farm gate price of paddy was estimated to be M$548/ton at 1983 constant price level based on the international price projections made by IBRD. Introducing certain assumptions on crop yield and crop intensity under with- and without-project conditions, the incremental benefit after full development with sufficient water is estimated to be M$129 x 10^6 per annum for the Kedah river system and M$31 x 10^6 per annum for the Muda-Perai river system.

Benefits arising from domestic and industrial water supply were estimated from the cost of the proposed Tawar-Muda dam as the least costly alternative facilites. The unit value of water would be dependent on the magnitude of the water deficit and was estimated to be M$0.24/$m^3$ for the Kedah river system and M$0.58/$m^3$ for the Muda-Perai river system.

The financial cost of the Beris dam project was converted to the economic cost by means of the national economic conversion factors prepared by EPU. The compensation cost on land was excluded but the agricultural production forgone due to flooding of the land was counted as an annual cost.

The economic cost of the Beris dam was estimated to be M$43.67 x 10^6 of investment cost and M$0.13 x 10^6 of annual costs including the production forgone and O&M costs.

The economic internal rate of return (EIRR) of the Beris dam was calculated to be 14.8% for Alternative 1 (Muda Priority), 14.8% for Alternative 2 (even distribution) and 14.6% for Alternative 3 (Kedah priority). This is satisfactorily high for any of the Alternatives. Thus the project is justifiable from the economic point of view.

For the overall water resources development, it was found that the implementation of the Reman dam in addition to the Beris dam would be economically justified, but that no further development would be justified. It is recommended, therefore, that any water deficit arising after the implementation of the Reman dam should be dealt with by means of water rationing.

14. Financial Analysis

According to the separable costs - remaining benefit method, the construction cost of the Beris dam of M$96.59 x 10^6 should be allocated to the agencies concerned as follows:

Unit: M$$10^6$

	MADA	Kedah DID	Kedah PWD	P.Pinang DID	P.Pinang PWA
Alternative 1	33.14	47.65	4.70	4.60	6.50
Alternative 2	36.70	45.95	4.86	2.58	6.50
Alternative 3	60.07	33.61	2.91	0	0

The O&M costs of the Beris dam to be allocated to irrigation purpose were estimated to be M$0.024/$m^3$ for MADA and M$0.025/$m^3$ for minor irrigation projects. These costs could be charged to the benefited farmers, as the incremental capacity to pay is estimated to be M$0.049/$m^3$ - M$0.059/$m^3$. The cost of water for domestic and industrial water supply was estimated to be M$0.26/$m^3$ for PWA and M$0.24/$m^3$ for Kedah PWD which include amortization of capital and O&M costs, being of the same order of present rate for domestic water use. These costs will push up the prevailing water rate, being mixed with costs of other existing facilities.

15. Supplemental Study

As a supplemental study, the water demand and supply balance was calculated on the assumption that new minor irrigation schemes in the Region will not be implemented after 1983.

The reduction of water demands and deficits due to the revision of minor irrigation water demands are summarized as follows together with the previous estimates with new minor irrigation schemes (called as original);

Unit: $10^6 m^3$

	Original	Revised	Difference
Demand 1990			
Kedah river	1,396	1,386	10
Muda-Perai river	655	581	74
Demand 2000			
Kedah river	1,474	1,434	40
Muda-Perai river	887	770	117
Deficit 1990			
Kedah river	358	354	4
Muda-Perai river	12	7	5
Deficit 2000			
Kedah river	399	384	15
Muda-Perai river	23	12	11

As for the operation rule of the Jeniang weir, the ceiling discharge for Alternative 2 should be revised to be $10 m^3/s$ due to changes in the water deficit in the Muda river. On the other hand, by the reduction of water in the Region, the possible off-season crop area of the MADA area would be increased by about 3% of the total MADA area in 2000.

The internal rate of return (EIRR) of the Beris dam would be 15.3% for both Alternatives 1 and 2 and 14.9% for Alternative 3 for the revised water demand.

The construction cost of the Beris dam would be allocated to agencies concerned as follows:

Summary of Cost Allocation for Revised Water Demand

Unit: M$$10^6$

	MADA	Kedah		Pulau Pinang	
		DID	PWD	DID	PWA
Alternative 1	58.72	19.26	6.64	5.12	6.85
Alternative 2	62.44	18.46	6.86	1.95	6.88
Alternative 3	74.58	17.96	4.05	0.0	0.0

16. Legal and Institutional Arrangement

The Federal Government is going to establish a legal system for the efficient implementation of water resources policies and plans and for the promotion of uniformity among water-related laws enforced by the States.

As interim measures until the above-mentioned legal system is established, it was recommended to make agreements between the Federal Government, the State Governments of Perlis, Kedah and Pulau Pinang, and MADA in order to promote coordinated actions for the regional water resources development and management. Following agreements are recommended:

(1) Master Agreement;
has been proposed in Part 1 Study and the following three matters are additionally proposed in this Study.

- Priority to take water,
- An implementation and management body, and
- Establishment of a Federal-States Committee.

(2) Regional Water Resources Master Plan;
as proposed in Part 1 Study.

(3) Agreements on Procedure and Methods;
should include methods and procedures of
- integrated operation of source facilities,
- Jeniang system operation,
- cost allocation,
- monitoring of intakes,
- reduction in off-season crop area in the MADA area, and
- water saving in the case of drought.

As an interim measure until the institutional system recommended by NWRS is implemented, it is recommended that a Federal-States Committee should be established with the objectives to establish principles and to coordinate actions in case of extraordinary drought.

It is recommended that the National Water Resources Development and Management Corporation should be established as an executing agency, to which the construction, operation and maintenance and monitoring of water uses be entrusted. The Corporation shall have the head office, regional control centers and site offices. The development expenditure of source facilities shall be transferred from the agencies which are responsible for the implementation of the facilities. Operation cost shall be charged to the agencies in accordance with the recurrent cost shearing.

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ABBREVIATIONS

(1) Organization/Plan

4MP (5MP)	:	Fourth (Fifth) Malaysia Plan
DID (JPT)	:	Drainage and Irrigation Department
EPU	:	Economic Planning Unit
FELCRA	:	Federal Land Consolidation and Rehabilitation Authority
FELDA	:	Federal Land Development Authority
IBRD	:	The World Bank
JICA	:	Japan International Cooperation Agency
MADA	:	Muda Agricultural Development Authority
MOH	:	Ministry of Health
MTR	:	Mid-Term Review of 4MP
NEB (LLN)	:	National Electricity Board
NWRS	:	National Water Resources Study
PWA	:	Pulau Pinang Water Authority
PWD (JKR)	:	Public Works Department
RESP	:	Rural Environmental Sanitation Program
RISDA	:	Rubber Industry Smallholders 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
HWL	:	Normal High Water Level
O & M	:	Operation and Maintenance
Q	:	Discharge
Ref.	:	Reference
SS	:	Suspended Solid
VA	:	Value Added

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

Derived Measures

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

Money

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

CONVERSION FACTORS

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

Exchange Rate

(at the end of 1983)

US$1 = M$2.312
¥100 = M$0.998

1. INTRODUCTION

1.1 Study Objective

The Perlis-Kedah-Pulau Pinang Regional Water Resources Study (the Study) has been carried out in order to formulate an integrated water resources development and management plan for the Perlis-Kedah-Pulau Pinang Region (the Region), to enable decisions to be made by the federal and state governments for implementation of water resources development projects. The Study was phased as follows.

Part 1-(December 1982 to February 1984) to formulate a long-term master plan for water demand and supply balance, flood mitigation and water pollution abatement, based on evaluation of present and future water resources problems and available resources.

It was demonstrated, in the Final Report for Part 1, February 1984, that the proposed Beris dam among proposed projects should be implemented by 1991, in addition to the on-going projects, in order to meet the immediate and future water demand in the Region.

Part 2-(December 1983 to March 1985) to study the feasibility of the Beris dam, to show detailed justification and other information for the implementation of the dam.

More specifically the objectives of Part 2 Study were:

(1) to make recommendations on water allocation and an integrated operation plan for the existing and proposed facilities;

(2) to prepare a preliminary design and cost estimate of the Beris dam project;

(3) to evaluate the Beris dam project from the economic, financial, social and environmental points of view; and

(4) to make recommendations on the implementation of the Beris dam project.

1.2 Technical Cooperation

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 had previously conducted the National Water Resources Study, Malaysia.

The Government of Malaysia appointed Counterpart Officers. The Government of Japan 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 Part 2 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 was established by JICA to review the findings by the Study Team. It was chaired by Mr. Y. Itobayashi, Director of 1st Construction Department, Water Resources Development Public Corporation, throughout Part 2 Study. The Steering Committee and the Advisory Committee maintained close liaison by meeting regularly to exchange views on the Study. The members of the Committees during Part 2 Study were as listed in Table 2.

1.3 Study Contents

Part 2 Study comprised:

(1) damsite and reservoir area surveys including topographical surveys, aerial photo mapping, core drilling, seismic exploration, material surveys, material tests and land use study to supplement information obtained in Part 1 Study;

(2) socio- and agro-economic studies to update the projections in Part 1 Study based on the Mid-Term Review of 4MP in socio-economy, domestic and industrial water supply, agro-economy and irrigation development;

(3) planning and design including additional hydrological studies, integrated dam operation planning, preliminary design of the project facilities, construction planning, cost estimates and analysis of project's impacts; and

(4) legal and institutional study including the study of subsidiary agreements to the "master agreement" which was proposed in Part 1 Study.

1.4 Final Report for Part 2

This Final Report for Part 2 consists of a Main Report and 12 Annexes; sectoral reports to support the Main Report. The studies in most sectors were detailed study based on the methodology and assumptions which were employed in Part 1 Study. It is, therefore, advisable that the Main Report and Annexes of Part 1 Study be referred to for a more comprehensive description of the study procedures.

1.5 Acknowledgement

The contribution to the Study by the officials of the 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. Heartfelt gratitude must also be recorded to officials of the Ministry of Foreign Affairs, Ministry of Construction and Embassy to Malaysia of the Government of Japan who have given advices and provided various supports in performance of the Study.

2. BACKGROUND

2.1 Perlis-Kedah-Pulau Pinang Region

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. The Region encompasses roughly the States of Perlis, Kedah and Pulau Pinang, but it does not include Pulau Langkawi and the Kerian river basin.

The population of the States of Perlis, Kedah and Pulau Pinang in 1980 was 2.2×10^6, of which 0.67×10^6 was urban population. The Region's economy is typically agricultural in the States of Perlis and Kedah, with tree crops for exports and rice production which amount to more than half of the national production, while it is industry based in the State of Pulau Pinang following to the Kelang valley's.

The main uses of water are for domestic and industrial water supply and for irrigation. The public water supply system is well developed, its service factor being 83% in Perlis, 68% in Kedah and 82% in Pulau Pinang. There are 133,500 ha of irrigated paddy fields in the Region, including 95,200 ha in the Muda irrigation project. The two-crop system is predominant. Existing dams are the Pedu, Muda and Ayer Hitam dams. The Kedah and Muda barrages are tidal barrages. The Perai barrage is a flood retention barrage.

Natural runoff can only be utilized to a limited extent, because it varies widely. It is estimated that a large water deficit takes place every year in the Kedah river system, though the Pedu and Muda dams can regulate the runoff to a great extent. In fact, insufficient water results in the cancellation of the off-season crop once in 6 years in the MADA area. There is no water deficit in the Muda river, which carries the largest amount of water in the Region, except in occasional dry years.

Rivers often overflow and inundate the land, because of their small channel capacity, but damage from floods does not occur annually. Over a long average, the annual flood damage is estimated to be M$9 x 10^6 and the population affected to be 25,000 under the socio-economic condition in 1982.

Most rivers in the Region can be classified as clean to mildly polluted in terms of BOD, but tributaries of the Merbok river and the main stream of the Juru river are highly polluted. The major pollutant sources are towns, rubber factories, palm oil mills, sugar mills and animal husbandry.

2.2 Main Conclusions of Part 1 Study

2.2.1 Water demand and supply balance system

Tertiary development in the MADA area is being carried out to increase and stabilize paddy production. Minor irrigation development is being promoted, in order to reduce the disparity in farmers' income between the MADA area and the other areas. The increased share of manufactured goods in exports as well as better urban living standard are inducing the continuous concentration of the population and industries into Pulau Pinang.

The tertiary development in the MADA area may reduce production costs, but it cannot increase paddy production, as long as a large water deficit persists as it does in the Kedah river system. Minor irrigation development will aggravate the water deficit in the Kedah river. A rapid increase in domestic and industrial water demand in Pulau Pinang coupled with minor irrigation development in the Muda river basin will increase the water deficit in the Muda river in volume and frequency.

Some source development projects are under construction or committed for implementation, in order to remove water deficit. The Timah-Tasoh dam and Arau dam envisaged for irrigation and flood control can balance the water demand and supply in the Perlis river up to 2000. The Ahning dam will be constructed in the Kedah river system for the purpose of water supply in Alor Setar and power generation. The Mengkuang dam in the Perai river system is being constructed by the Pinang Water Authority for the purpose of water supply. The Jeniang system is contemplated to divert water from the middle stretch of the Muda river to the MADA area.

The existing Pedu and Muda dams, as well as the ongoing Jeniang system and Ahning dam all aim at balancing water demand and supply in the Kedah river system, but these source projects are still not enough to meet all the water deficit. Implementation of additional source projects is necessary for reliable supply of water.

An analysis in Part 1 resulted in a recommendation that the Beris dam among the proposed 6 dams should be implemented in the immediate future, in addition to the Jeniang system and the other ongoing source projects.

There are other potential source projects, though they cannot be implemented in the immediate future, due to either social/political constraints or immaturity in investigation. The residual water deficit should be mitigated by minimizing water demand for the time being. The potential projects to be considered for greater reliability in supply are the Reman dam, Merbok storage and Khlong Thepha dam.

2.2.2 Flood mitigation plan

Major flood problem areas are Kangar, Kuala Nerang, Kuala Ketil, part of Butterworth and Georgetown.

A flood mitigation plan was proposed with an assumed target to reduce more than 50% of affected population and damage by 2000. The plan includes the undertaking of 93 km of channel improvement, construction of a 22 km bypass floodway, 2 dams and a retarding basin on the assumption of high economic growth (High Growth Case), and the improvement of 70 km channel, construction of 2 dams and a retarding basin in the case of low economic growth (Low Growth Case).

2.2.3 Water pollution abatement

Increased water use will cause aggravation in river water quality in the future, though at present water pollution is found only in limited river stretches.

A water pollution abatement plan is proposed, on the assumption that the standard BOD concentration will be less than 5 mg/l in a river stretch where an intake is located and less than 10 mg/l elsewhere.

It is recommended that all rubber factories, palm oil mills and sugar mills should install adequate treatment facilities for their effluents as required by DOE, sewerage system should be provided in Kangar, Alor Setar, Sg. Petani and Kulim, and the ongoing sewerage development for Butterworth and Georgetown should be continued as scheduled.

The requirement of river maintenance flow was studied from the view point of preserving river water quality. Other aspects of river maintenance flow are not significant in the Region. In the upper and middle stretches of these rivers, water can be kept clean because runoff is augmented by stored water for the downstream water use or the pollutant load is very small. Augmentation of runoff for the special purpose of pollution abatement is necessary, however, in the lower reaches of the Perlis and Kedah rivers.

2.2.4 Legal and institutional arrangement

If the Jeniang system is implemented the major rivers in the Region will constitute a single system from the viewpoint of the water demand and supply balance. For the proper development and management of this region-wide water resources system, it is necessary to make some legal and institutional arrangement so that the States of Perlis, Kedah and Pulau Pinang can enjoy reasonable and equitable shares in the beneficial use of water and they may collaborate in the development and management of water source projects.

The arrangements necessary for regional water resources development and management will be stipulated in the National Water Code which is being prepared by the Government. As an interim measure before the Code is enforced, it is recommended that the "master agreement" be made among the Federal Government and the Governments of the three States. The agreement should stipulate that (1) a regional water resources master plan shall be formulated and authorized by the Federal and State Governments, (2) the allocation of water in the Region to each State shall be agreed upon by the three States, (3) all source facilities in the Region shall be integratedly operated according to rules approved by the three States, (4) the costs for the development and management of water source facilities shall be equitably allocated among the Federal and State Governments, and (5) the Federal Government shall submit an arbitration proposal at the request by one of the three States, if there is a dispute.

2.3 Updating of Socio-Economic Projection

The socio-economic projection in the Study were made not for making any proposal for the socio-economic development but to provide certain socio-economic figures conceivable for the future according to the context of the Malaysia Five Years Development Plans to the extent necessary for the water demand projection.

The socio-economic projections were based on the fourth Malaysia Plan (4MP) in Part 1 Study but updated in Part 2

Study based on the Mid-Term Review (MTR) of 4MP, which was published after Part 1 Study was completed.

The main differences between 4MP and MTR for 1980 and 1985 were as follows: the population of Malaysia has declined by 4.5% based on the final figure of 1980 Census (Ref. 1). The average annual growth rate of gross domestic product (GDP) between 1980 and 1985 was adjusted from 7.6% to 6.7% based on actual data to date.

The tables entitled "Malaysia: Gross Domestic Product by Industry of Origin and State" for 1980, 1983 and 1985 shown in MTR were the principal references for projecting population and GDP. The same table for 1971 in 4MP was also referred to. No projected figures were published for years beyond 1985, but unpublished figures of population in Malaysia for 1990 and 2000 were provided by the EPU Regional Section in June 1984. Regarding GDP, the annual growth rate was assumed to be 7.5% for 1985 - 1990, 7% for 1990 - 1995 and 6.5% for 1995 - 2000. The EPU Macro Section had no objection to use of these figures for the projection of water demand, during an explanation session made by the Study Team in June 1984.

The updated projection is summarized for population in Table 3 and for GDP in Table 4.

The new population projection is smaller by a few percentage points than in the previous one. As for GDP projection in Part 1 Study, the projection following the figures for 1980, 1985 and 1990 in 4MP assumed average annual growth rates of 7.6% for 1980 - 1985, 8.4% for 1985 - 1990 and 7.5% for 1990 - 2000. The gross regional product (GRP) of the States of Perlis, Kedah and Pulau Pinang in 2000 was estimated this time to be M$13.4 x 10^9, as against M$15.9 x 10^9 in the previous estimate.

In Part 1 Study, the above-mentioned case was called High Growth Case and another case assigning average annual growth rates of 6% for 1980 - 1985, 5% for 1985 - 1990 and 4% for 1990 - 2000 was named Low Growth Case. Only a case corresponding to High Growth Case is assumed in Part 2 Study, because the economy of the source facilities is little sensitive to the economic growth rate if all the water deficit cannot be removed, as in this Region.

3. REGIONAL WATER DEMAND AND SUPPLY BALANCE SYSTEM

3.1 Domestic and Industrial Water Demand

Public water supply is administered by the Water Supply Division of the 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 in the State of Pulau Pinang.

According to the latest available figures, annual totals of water supplied were 3 x 10^6m^3 in 1978 by Perlis PWD, 45.6 x 10^6m^3 in 1981 by Kedah PWD and 86.3 x 10^6m^3 in 1982 by PWA.

Under the Rural Environmental Sanitation Program (RESP) with materials and technical advices from MOH, the state governments have installed untreated water supply systems in the interior and isolated rural areas, by either taking water from small streams or digging shallow wells equipped with hand pumps. The population served by RESP in the three States was 166,000 in 1980.

As a preliminary target for the public water supply system development, which includes PWD/PWA and RESP systems, the service factor for domestic water supply in 2000 was assumed to be 100%. The service factor for industrial water supply was assumed to be 90%, after revising the previous estimate of 50% for the States of Perlis and Kedah on the advice of officials concerned.

The projected domestic and industrial water demands within the Region are summarized in Table 5. The domestic water demand of 106 x 10^6m^3 in 1983 will increase to 256 x 10^6m^3 by 2000. Industrial water demand of 95 x 10^6m^3 in 1983 will grow to 304 x 10^6m^3 by 2000. Compared with the projected figures in Part 1 Study, the domestic water demand is slightly adjusted, but the industrial water demand in 2000 in the revised estimate is at about 67% of the previous estimate (High Growth Case), corresponding to the reduction in GRP and adjustment of growth rate of water-intensive industries in the State of Pulau Pinang. As a whole, domestic and industrial water demands in 2000 in the Region were estimated to be 560 x 10^6m^3, which is 21% less than the previously estimated 709 x 10^6m^3 for High Growth Case. In the State of Perlis within the Region, the domestic and industrial water demand of 9 x 10^6m^3 in 1983 will increase to 30 x 10^6m^3 by 2000. In the State of Kedah within the Region, domestic and industrial water demand will increase from 54 x 10^6m^3 in 1983 to 199 x 10^6m^3 in 2000. In the State of Pulau Pinang, domestic and industrial water demand of 138 x 10^6m^3 in 1983 will grow to 330 x 10^6m^3 by 2000.

3.2 Irrigation Water Demand

According to the results of Part 1 Study, there were 121,820 ha of irrigation areas including the MADA area of 95,800 ha and 69 minor irrigation schemes of 26,020 ha (excluding control drainage schemes) in 1982 in the Region. For future development, it was assumed that tertiary development would be completed in the whole MADA area and all potential irrigation schemes would be implemented by 2000. Irrigation areas in 2000 were, thus projected to be 132,480 ha including 93,000 ha in the MADA area and 237 minor irrigation schemes covering 39,480 ha. In relation to the tertiary development in the MADA area, the area not provided with tertiary development is called the Muda I area, the area of 24,800 ha delineated for the present tertiary development project is named the Muda II area, and the area not included in the Muda II area but to be provided with tertiary development in the future is called the Muda III area. According to the results of tertiary development to date, a reduction in the irrigation area due to land acquisition for the tertiary facilities was taken to be 4% of the original irrigation area.

Kedah DID has 1,864 ha of minor irrigation schemes which depend on water from the MADA canal through off-takes. These schemes were called the MADA minor area in Part 1 Study, but they are now called the fringe areas, in accordance with Kedah DID's practice. Minor irrigation schemes of 5,604 ha including fringe areas of 2,457 ha have been identified by Kedah DID and were assumed to be implemented by 1990 in Part 1 Study. The development of these new fringe areas, however, has been totally omitted from the projections in Part 2 Study in accordance with the policy recently expressed by Kedah State Authorities, because all the water shortage problem in MADA cannot be solved even with possible water source development by 2000.

With the above-mentioned modifications, the irrigation area in 2000 in the Region is estimated to be 127,724 ha, including the MADA area of 92,000 ha, fringe areas of 1,864 ha and other minor irrigation schemes of 33,860 ha.

A scheduled irrigation method was assumed for all the irrigation areas in Part 1 Study, because routine adjustment of water is difficult due to the slow response of field moisture to water applied, in a system of low canal density, which is predominant in the Region.

The scheduled irrigation method is herein defined as a method of water diversions at a rate which is pre-determined for each 10-day period during the growing period, so that adequate water is available except under certain dry conditions. This assumption has been followed in Part 2 Study for the minor irrigation schemes but some different assumptions have been assumed for the MADA and fringe areas.

On the basis of comments and opinions expressed in a workshop which was held on July 9, 1984 at MADA headquarters, the following modifications were made to the irrigation method to be assumed in the MADA and fringe areas: (1) The traditional nursery system is assumed instead of the separate nursery system, (2) soil saturation depth is assumed to be 125 mm instead of 90 mm, and (3) a controlled irrigation method is introduced instead of the scheduled irrigation method, on the assumption that the proposed telemetering system is implemented.

In the controlled irrigation method, the diversion discharge is pre-determined for each week in the growing period, as in the scheduled irrigation method. High water level (HWL) and low water level (LWL) are determined in a terminal plot. The diversion discharge for a week is adjusted either to that specified for the week if the water surface in the terminal plot is lower than LWL at the end of the previous week or to the smaller one between the discharge in the previous week or that specified for the week if the water surface is between HWL and LWL or to zero if the water surface is higher than HWL.

The water demands in the MADA area were estimated to be 1,278 x $10^6 m^3$ for 1990 and 1,243 x $10^6 m^3$ for 2000, which is 14% smaller than the previously estimated 1,485 x $10^6 m^3$ for 2000.

Projected irrigation water demands in the Region are summarized in Table 6. Total water demand in 2000 were estimated to be 1,959 x $10^6 m^3$, or 13% less than the previous estimate of 2,246 x $10^6 m^3$.

3.3 Water Demand and Supply Balance System

A diagram of the water demand and supply balance system covering the whole Region is illustrated in Figs. 1 and 2. The system related to the proposed Beris dam covers not all but most parts of the Region, herein named the Kedah-Muda-Perai river system. It encompasses the Kedah, Muda and Perai river systems and most rivers in Pulau Pinang. Water demands in the Kedah-Muda-Perai river system projected for 1983, 1990 and 2000 are summarized in Table 7 which needs to be read in conjunction with Fig. 3, which illustrates the Kedah-Muda-Perai river system in a diagrammatic form.

According to the results of Part 1 Study, a river maintenance flows of 2.7 m^3/s in 1990 and 5.9 m^3/s in 2000 will be necessary in the Kedah river below Alor Setar to keep the BOD concentration below 10 mg/l. This however assumes that sewerage development and improvement of effluent purification system are implemented as proposed in Part 1 Study.

3.4 Water Deficit

Runoff occurring in the main stream is the natural runoff deducted by water withdrawn by water users in the tributaries. It reduces with increase in water uses in the tributaries. Part of the runoff in the main stream is available for use, but the much is discharged into the sea as flood flow. The difference between the water demand in the main stream and the available runoff in the main stream represents the water deficit. Water released from a dam reduces the water deficit.

Water deficits in 1983, 1990 and 2000 were estimated for the Kedah and Muda-Perai river systems by means of a water demand and supply balance model, assuming that only the existing dams such as the Pedu, Muda and Ayer Hitam dams were operated. The calculation was conducted on the basis of 5-day runoff record for 23 years between 1961 and 1983. The results are shown in Fig. 4 as a relationship among estimated river runoff, water demand, water output from the existing dams and water deficit in the main stream.

In the Kedah river system, the river runoff consists of the inflow into the Pedu dam including water diverted from the Muda dam and the residual runoff below the Pedu dam. A small part of the residual runoff is withdrawn by the water demand in tributaries before coming into the main stream. The difference between tributary water demand and tributary water withdrawal is tributary water deficit, which cannot be eliminated unless tributary flow is augmented during the deficit period. Water demand in the main stream comprises the irrigation water demand in the MADA and fringe areas, that in minor irrigation shemes, domestic and industrial water demand, and river maintenance flow. The water demand in the MADA area decreases with the progress of tertiary development. The water demand is met by uncontrolled river flow and regulated outflow from the Pedu dam. The difference between demand and supply represents the water deficit in the main stream. According to an analysis, the water deficit in the Kedah river system is already very large and occurs almost every year. The water deficit was calculated to be 408 x 10^6m^3 for 1983, 404 x 10^6m^3 for 1990 and 444 x 10^6m^3 for 2000, on an average for 1961 to 1983.

The Muda-Perai river system consists of the Muda river, Perai river and some rivers in Pulau Pinang. The water supply system in Seberang Perai diverts water to that in Pulau Pinang, because the Ayer Hitam dam and the rivers in Pulau Pinang cannot meet all the domestic and industrial water demand of the island. The water supply system in Seberang Perai takes water from the Perai river and from the lower reaches of the Muda river via the River Muda Canal.

The Pinang Tungal, Sg. Kulim and Sg. Jarak irrigation schemes located in the Perai river basin take water from tributaries of the Perai river as well as from the lower reaches of the Muda river. Consequently, the water demand in the main stream of the Muda river comprises irrigation water demand solely depending on the Muda river and the supplemental water demands of the water supply system of Pulau Pinang and Seberang Perai and the Pinang Tungal, Sg. Kulim and Sg. Jarak irrigation systems. Available water in the main stream is uncontrolled flow only unless water is released from the Muda dam. According to an analysis assuming the hydrological condition in 1961 to 1983, a water deficit will occur only between

January and July, and mostly in March and April. It will be quite small and will occur only in 9 years out of 23 years under the 1983 demand conditions but will rapidly increase, due to the increase in domestic and industrial water demands in the State of Pulau Pinang and to increased irrigation demands for minor irrigation development on tributaries and in the lower reaches of the main stream in the State of Kedah. The 23-year average annual water deficit was calculated to be $7 \times 10^6 m^3$ for 1983, $17 \times 10^6 m^3$ for 1990 and $35 \times 10^6 m^3$ for 2000.

The Mengkuang dam is under construction to increase the capacity of the water supply system in Seberang Perai. During the wet season, excess water of the Kulim river and the Muda river is pumped up into the Mengkuang reservoir with a $23.7 \times 10^6 m^3$ effective storage capacity. Water will be released from the storage when a water shortage occurs in the water supply system. The average annual output of the dam was estimated to be $5 \times 10^6 m^3$ for 1990 and $12 \times 10^6 m^3$ for 2000 demand. The average output appears small because the reservoir full capacity will be utilized only in very dry years.

The Ahning dam is to be constructed for supply of water to Alor Setar and for power generation. If there is any surplus capacity, it can be utilized for other purposes as well. The average annual output of the dam was estimated to be $46 \times 10^6 m^3$ for 1990 and $45 \times 10^6 m^3$ for 2000.

In the cost allocation and analysis of the effect of a water resources project, it was necessary to identify the persons who would cause water deficit and those who would be affected by water deficit. This problem was investigated on the assumption that the Mengkuang and Ahning dams would be completed before 1990.

Water users were classificed as follows:

For the Kedah river system:

(1) MADA; the major irrigation scheme in the MADA area

(2) Main minor; minor irrigation scheme depending on offtake of the MADA canal (fringe area) and the main stream of the Kedah river.

(3) Tributary minor; minor irrigation schemes depending on tributaries, where no source facilities are assumed upstream.

(4) D&I; domestic and industrial water supply

For the Muda-Perai river system:

(1) Main minor; minor irrigation schemes depending on the main stream of the Muda river.

(2) Tributary minor; minor irrigation schemes depending on tributaries of the Muda and Perai rivers.

(3) D&I; domestic and industrial water supply for Muda and Perai river systems including Pinang island.

The water deficit is expressed as the average annual volume for the 23-year period. The water deficit in 1983 after the output of the Pedu-Muda dam is deducted is regarded as caused by the existing water users in proportion to the water demand. In the case of the Muda-Perai river, the withdrawal from the Muda main stream is regarded as the demand. In future years, the incremental deficit will mostly occur during the period in which the uncontrolled river runoff is already used up by existing users or when the incremental demand of a purpose is larger than the remaining runoff. Thus it is assumed that the incremental water deficit will be allocated to users in proportion to the incremental demand after 1983. In other words, the remaining river water will be allocated to users in proportion to the incremental demand based on the scheduled demand conditions in 1990 and 2000.

Let us assume that water demand and supply has been marginally balanced in a river system. A new water user in a tributary will cause water deficit to the existing water user in the main stream. A new water user in the main stream will also do the same but he may suffer from water deficit, which will be caused by himself. Consequently, the cause of a water deficit is generally different from the area affected by the water deficit.

The water deficit caused by one user affects the users along the main stream. As described in the following chapter, it was assumed that the D&I water demand has priority to take river water over the irrigation water demand and therefore the MADA and the Main minor irrigation projects are affected by the water deficit in proportion to the water demand in the Kedah river system while the Main minor irrigation only is affected by the water deficit in the Muda-Perai river system. Table 8 shows the estimated average annual water deficit by cause of water deficit by area affected by water deficit, in which the net water output of the Ahning dam and the Mengkuang dam has been deducted from the water deficit caused by D&I in the Kedah and Muda-Perai rivers. In 1990 when the output of these dams are larger than the water deficit caused by D&I, surplus water will be allocated to other users.

The 23-year average annual water deficit in 1983 in the main stream of the Kedah river was estimated to be $409 \times 10^6 m^3$, mainly affecting the MADA area. It is classified by cause to be $390 \times 10^6 m^3$ for the MADA area, $14 \times 10^6 m^3$ for minor irrigation schemes and $5 \times 10^6 m^3$ for domestic and industrial water supply. The incremental water deficit between 1983 and 2000 caused by minor irrigation projects will be $15 \times 10^6 m^3$ and that caused by domestic and industrial water supply will be $11 \times 10^6 m^3$. Furthermore, $14 \times 10^6 m^3$ of water deficit will have to be added by the increased river maintenance flow. On the other hand, the water deficit caused by the MADA area will be reduced owing to the tertiary development. Consequently the total water deficit in the Kedah river system will be reduced by 10 x $10^6 m^3$ between 1983 and 2000. It is noteworthy that the development of minor irrigation schemes contributes significantly to water deficit in the main stream, especially to the MADA area. Water deficit caused by domestic and industrial water demand in 1990 was assumed to be zero, due to the Ahning dam becoming operational.

Water deficit in 1983 in the Muda main stream was estimated to be 7 x $10^6 m^3$ consisting of 6 x $10^6 m^3$ caused by minor irrigation schemes and 1 x $10^6 m^3$ caused by domestic and industrial water supply. The operation of the Mengkuang dam will reduce the water deficit caused by domestic and industrial water supply to nil in 1990. Between 1983 and 2000, the incremental water deficits will be 11 x $10^6 m^3$ caused by minor irrigation development in the State of Kedah and 6 x $10^6 m^3$ caused by the increase in domestic and industrial water demand, which could be further divided into 2 x $10^6 m^3$ for the State of Kedah and 4 x $10^6 m^3$ for the State of Pulau Pinang. On the other hand, the water deficit will be decreased by 1 x $10^6 m^3$ due to tertiary development of the minor irrigation schemes in the State of Pulau Pinang. Overall, the incremental water deficit will be 16 x $10^6 m^3$ in the Muda main stream.

4. POLICY FOR WATER DEMAND AND SUPPLY BALANCE

4.1 Assumed Target of Safe Supply

Risk of safe supply is incidental in balancing water demand and supply. Water can be supplied to a wide area, if a large risk is acceptable, but there is a limit that the risk can be endured by the water users.

A water demand and supply balance plan should be formulated based on a target of safe supply, which is expressed by some parameters representing the risk of safe supply. Referring to design criteria in Malaysia, the target is herein assumed, for the hydrological condition of the 23-year period between 1961 and 1983, as follows:

> For domestic and industrial water supply, safe supply should be guaranteed even under the driest condition. For irrigation, (1) number of deficit year should not be more than 5, (2) percentage of average annual water deficit to average annual water demand should not be more than 1%, and (3) the greatest percentage of water deficit in a month to water demand in the same month should not be more than 50%.

4.2 Priority to Take Water

Irrigation water use should be reduced under a dry condition, while domestic and industrial water use is given an inviolable priority in the target assumed in Section 4.1. Uniform reduction in water use is not necessarily possible and a priority order to take water is set among irrigation project.

The minor irrigation projects in the tributary basins depend on unregulated flow, being designed against a drought which occurs once in 5 years. Most of them are marginally viable. Moreover, these projects are generally small and spread over a wide area. Water saving in these projects is difficult and it may hurt economic viability of the projects. It is recommended that the minor irrigation projects in the tributary basin should be given priority over those depending on the main streams.

There is no socio-economic reason that priority order should be established among the irrigation projects which are depending on the main streams, but the projects in the upstream reaches usually have priority over those in the downstream reaches unless artificially regulated. Uniform water saving can be conducted by adjusting water use in the upstream reaches, because only a few intakes are located in the upstream reaches of the main stream. It is recommended that all irrigation projects in the upstream reaches and downstream reaches of the main stream should be given equal priority.

An existing project should have priority over a new project, in principle, but it is recommended that the existing and new projects should be given equal priority, for the time being, because new projects have to be implemented though water deficit already takes place in existing projects.

A study on the priority order between the Kedah river basin and Muda river basin is described in Chapter 5.

4.3 Safe Supply Measures

Water demand in the Kedah river system is estimated to be 83% of river flow, indicative that water resources in the Kedah river has been overexploited. It is further estimated that the targest of safe supply assumed in Section 4.1 cannot be attained unless water demand is reduced, even if source projects including the Jeniang system are implemented.

It is necessary to adjust the off-season crop area in the MADA area, in order to avoid frequent and serious drought damage. Off-season crop area should be 25% under the demand condition in 1983, unless available water is predicted before the off-season starts. An analysis showed that the prediction would be possible with a high accuracy owing to the large storage capacity of the Pedu dam, and off-season crop area would be 54% on average under the 1983 demand condition. It is recommended that off-season crop area should be adjusted to available water which is predicted on the basis of the water level in the Pedu reservoir before the off-season starts.

5. INTEGRATED SOURCE FACILITIES OPERATION STUDY

5.1 Alternative Water Allocation Rules at Jeniang Weir

The purpose of the source development is to alleviate the water deficit with surplus water which would otherwise run to the sea unused. Normally surplus water is found in the wet season but the water deficit takes place in the dry season. In the Kedah river system, a large water deficit takes place even in the wet season and surplus water appears only occasionally in times of flood. Surplus water diverted from the Muda-Perai river system at the Jeniang barrage will be conveyed into the Naok dam. It will be released immediately to supply the wet season water deficit in the Kedah river system but $27 \times 10^6 m^3$ will be retained in the Naok reservoir for the use in the next dry season.

Based on preliminary proposals in the Draft Final Report of the Jeniang Team (Ref. 2), it was assumed that a double way canal or other means will be provided to enable the Jeniang system to command not only the southern area but the northern area of MADA. This assumption is only temporary because the feasibility of the double way canal has not been proven yet. Exclusion of this assumption does not affect the feasibility of the proposed Beris dam but the water output of the Jeniang system reduces by $12 \times 10^6 m^3/y$.

The operation rules for the Jeniang weir should neither cause nor increase water deficit in the Muda-Perai river system nor reduce the river flow immediately downstream of the weir below a determined rate, which it is assumed would be the minimum recorded runoff of 2 m^3/s between 1961 and 1983. In relation to the allocation of water between the water users in the Kedah river system and those in the Muda-Perai river system, three alternative rules of the Jeniang system have been examined:

Alternative 1: Assuming priority for existing and future water users in the Muda-Perai river basin, the Jeniang weir would be allowed to take water, only if it does not affect the off-takes above the Muda barrage.

Alternative 2: As a compromise, water deficit would be allocated to the Kedah river system and to the Muda-Perai river system in order to attain the target of safe supply both in the two river systems.

Alternative 3: Assuming priority for the Kedah river, the Jeniang weir would be permitted to take water unless it would increase the water deficit which would affect otherwise existing and future water users up to 2000 in the Muda-Perai river system.

No restriction would be placed on releasing water over the Jeniang weir to meet the downstream water deficit in Alternative 1, but some ceiling should be set for Alternatives 2 or 3. The ceiling discharge over the Jeniang weir to meet the downstream water deficit should be 15 m^3/s for Alternative 2 and 2.5 m^3/s for Alternative 3. These figure were derived from estimates of frequency and annual average and maximum monthly water deficits in the Muda river under conditions of with and without the ceiling discharge.

5.2 Output of Jeniang System and Beris Dam

The average annual net water output by the Jeniang system was estimated to be 182 x $10^6 m^3$ for 1990 and 185 x $10^6 m^3$ - 187 x $10^6 m^3$ for 2000, on the assumption that the Pedu, Muda, Ahning, Mengkuang and Ayer Hitam dams will be operational. It is noted that the annual supply capacity of the Jeniang system would be almost the same whichever of the above alternative rules is adopted. The Jeniang system will not increase the average water deficit in the Muda-Perai river system under any of the alternative rules in Section 5.1, though it may shift the water deficit from one period to another.

The average annual output of the Beris dam was estimated to be 62 - 66 x $10^6 m^3$. As the water demand in the Muda river basin increases, the allocation of the Beris output to the Kedah river system would increase from Alternative 1 to Alternative 3.

The remaining water deficit with the Jeniang system and Beris dam was estimated to be 123 - 126 x $10^6 m^3$ for 1990 and 169 - 171 x $10^6 m^3$ for 2000.

The output of the Jeniang system and Beris dam can be calculated being divided into the supply to the Kedah river system and that to the Muda-Perai system, but the allocation of output to the cause of water deficit is rather arbitrary.

As the basic information to show the distribution of the responsibility for the implementation of the source development projects, the output of the Jeniang system and Beris dam and the remaining deficit were determined by cause of water deficit from the following assumptions.

The Jeniang system would be constructed to supply water deficits in MADA, minor irrigation projects in the main stream, and domestic and industrial water supply, both existing and anticipated in the Kedah river system up to 2000.

The Beris dam would be constructed to cover all water deficit caused by the increase in domestic and industrial water supply demand and by minor irrigation development in tributaries in both the Kedah and Muda-Perai river systems, and part of the remaining water deficit in MADA and main minor irrigation projects in the Kedah river and Muda-Perai systems.

A proposed allocation of outputs of the Jeniang system and Beris dam to the causes of the water deficits, based on the above-mentioned assumptions is summarized in Table 9.

If the other potential source facilities, Reman and Khlong Thepha dams would be implemented, the remaining water deficit in 2000 would be 42 x $10^6 m^3$ for Alternative 1, 44 x $10^6 m^3$ for Alternative 2 and 60 x $10^6 m^3$ for Alternative 3. In case that Merbok storage would be added for Alternative 3, the remaining water deficit would be 37 x $10^6 m^3$ but the Merbok storage would not be effective for the other Alternatives.

Table 10 shows the net water output of the source facilities and the remaining water deficit for the three Alternatives.

5.3 Operation Rule

The future operation rule for the source facilities of the Kedah-Muda-Perai river system was studied by trials and errors, assuming operation at 5-day intervals under the hydrological condition of the 23 years between 1961 and 1983.

The features of the major source facilities such as the Pedu-Muda dam system, Ahning dam, Jeniang system and Beris dam were assumed to be as shown in Table 11.

The objectives of the operation rule will be to maximize the deficit supply by minimizing spillout and spreading the remaining water deficit over a long time. There will not be sufficient water to irrigate the whole area in the off-season crop period from February to June if the water level in the Pedu reservoir is not higher than El. 91 m at the beginning of February. In this case, the off-season crop area in the Kedah river system will have to be reduced and the maximum outflow from the Ahning dam restricted, according to the water surface elevation in the Pedu reservoir at the beginning of February. If the drawdown in the Pedu reservoir during March is larger than 6.5 m, the off-season crop area will have to be further reduced.

If the water level in the Pedu reservoir falls below El. 75 m, water rationing will be required irrespective of the time of the year. The maximum outflow from the Beris dam would normally be 15 m^3/s but it would be reduced to 5 m^3/s if the water level in the Beris reservoir falls below El. 75 m.

For Alternative 1, however, it was assumed that the water stored in the Muda dam should be released to the Muda river in an extraordinary dry year when the Beris dam cannot fulfill the water deficit in the Muda river, even if two units of outlet valve of the Beris dam are simultaneously operated.

5.4 Risk of Safe Supply of Alternatives

Table 12 shows the risk of safe supply in the main minor irrigation in the Muda river assuming the hydrological condition of the 23-year period. In Alternative 1, no water deficit will take place even under the driest condition. In Alternative 2, number of water deficit yars will be 7 in 1990 and 8 in 2000, percentage of average annual water deficit to average annual water demand will be less than 1% and the greatest percentage of water deficit in a month to water demand in the same month will be less than 30%. In Alternative 3, number of water deficit years will be 14 in 1990 and 17 in 2000, percentage of average annual water deficit to average annual water demand will be 4% in 1990 and 8% in 2000, and the greatest percentage of water deficit in a month to water demand in the same month will be 65% in 1990 and 90% in 2000.

5.5 MADA Off-season Crop Area

In the Kedah river basin, the planting area of off-season cropping in the MADA irrigation area should be adjusted at the beginning of February and April based on the water level of the Pedu dam as described in Section 5.3. On the basis of the operation study, the off-season crop area in the MADA area was estimated for selected combinations of source facilities for three Alternatives under the condition that the target of safe study is as assumed in Section 4.1. Table 13 shows the average crop area in the MADA area and its proportion to the total area for the 23-year period.

5.6 Recommended Alternative

If Alternative 1 is taken up, problem regarding the allocation of water in the Muda river will be minimum between the States of Kedah and Pulan Pinang, because no water deficit will take place in the Muda river, except in an extraordinarily dry year which was not experienced between 1961 and 1983. On the other hand, the irrigation projects in the State of Kedah will be operated under different risks of safe supply according to the river basins. Release of water from the river outlet of the Muda dam will be sometimes necessary. That will reflect on the off-season crop area of the MADA area, as estimated to be 76,000 ha or 80% of the total MADA area on an average, being smaller by 1,000 ha than that of Alternative 2.

Alternative 2 can meet the assumed target of safe supply except the number of water deficit years. Some deficits will last only a short period. If these deficits are disregarded because of their weak impact, the target of safe supply will be met also in the number of water deficit years. Equal priority is assumed to the Muda and Kedah river basins, but water allocation problem will be more frequently solved between the States of Kedah and Pulau Pinang. Off-season crop area in the MADA area will be 77,000 ha or 81% of the total MADA area.

Alternative 3 cannot meet the assumed target for safe supply in the Muda river. Priority of the recipient basin over the donor basin is not persuasive. Off-season crop area in the MADA area will be the largest of 80,000 ha, or 84% of the total area.

Alternative 3 is not recommendable because of large risk of safe supply in the Muda river. There is no decisive factor for the selection between Alternatives 1 and 2. Only from the viewpoint of equality in the Region, Alternative 2 is herein recommended.

Three Alternatives are equally handled in the subsequent descriptions.

5.7 Monitoring

For the purpose of operating the source facilities in the integrated river system, it is recommended that a control center be established with responsibility for giving operational instructions to all the source facilities including the Pedu, Muda, Ahning and Beris dams, and the Pelubang, Jeniang, Kedah and Muda barrages.

Furthermore, the following monitoring points should be established for the purpose of identifying and quantifying the water deficit for which the source facilities are operated; the Pelubang barrage for the Kedah river and the Jeniang weir for the MADA area, which are located immediately upstream of the major intake structures. The Victoria Estate hydrologic station would be an appropriate monitoring point for the Muda downstream area since the main demands on the Muda river come from in the stretch between the station and the Muda barrage and it can be assumed that the inflow from tributaries entering this stretch will be negligible. The station is located near the boundary of the States of Kedah and Pulau Pinang.

An appropriate communication system should be established between the control center, the source facilities and the monitoring points. Because the locations of these facilities are widely dispersed in the Kedah-Muda river system, an exclusive radio-communication system is recommended.

The control center should collect information on the water demands of all water users in the system at the beginning of every year and prepare demand tables for the monitoring points on a 5-day basis throughout the year. The demand for off-season crops in the MADA area will have to be determined, however, on the first of February and on the first of April by referring to the Pedu water levels.

The demand in the MADA area will have to be adjusted at the beginning of every 5-day period by the MADA office according to information on field water levels.

The source facilities would be operated to sustain the river discharge according to the above-mentioned demand at the monitoring points.

Instructions for the operation of source facilities should be given at 5-day intervals.

The water available at the demand center on the main river would be the sum of the uncontrolled flow of the river and release from the source facilities located upstream of the demand center. It is assumed that the rate of uncontrolled flow available for a 5-day period would be equal to that in the previous 5-day period for the purpose to determining the water deficit to be supplemented by releases from the source facilities.

The runoff coming into the pool created by the Muda barrage would be the discharge observed at the Victoria Estate hydrological station. The uncontrolled flow would be given as the observed river runoff less the release from the Jeniang weir.

The above-mentioned operation procedure will require the follwoing information of source facilities and monitoring points. The information should be gathered daily but should be collected by the control center on the last day of a 5-day period.

(1) Dams

Facilities: the Pedu, Muda, Ahning and Beris dams if they are implemented,

Information: reservoir water level,
release and spill from the reservoir,

Furthermore, it is recommended that pan evaporation at the damsite and rainfall at the damsite and other sites in the catchment area to be observed daily to provide valuable data for future studies of source facilities and the refinement of the operational system.

(2) Pelubang and Jeniang barrages

Information: intake water level,
withdrawal discharge,
release to downstream

(3) Victoria Estate hydrologic station (Muda river)

Information: water level of the Muda river,

The discharge measurement at the site shall be conducted at least once a month to check the stage-discharge curve of the station which should be periodically updated.

(4) Muda barrage

Information: water level of the pool created by the barrage,
release to the Muda estuary,
withdrawals by pumping station along the pool above the barrage

(5) Kedah barrage

Information: release to the Kedah estuary,
BOD concentration which is required in the dry season if the release from the barrage is less than 2.7 m^3/s in 1990 or 5.9 m^3/s in 2000