ANNEX F

STUDY ON OPERATION OF WATER RESOURCES SYSTEM

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1. INTRODUCTION

The regional water demand and supply balance study has been carried out for Part 1 Study under the hydrological conditions for 20-year period from 1961 to 1980. In Part 2 Study, the regional water demand and supply balance was calculated by using the runoff data extended to the end of 1983 and the updated demand data.

For the water balance calculation of the uncontrolled flow, the procedure and assumptions were the same as those applied in Part 1 Study as described in Section 4.

In Section 5, a model of the integrated river system of the Kedah-Muda-Perai rivers was constructed to simulate the behavior of the source facilities in the river system and integrated operation rules of these facilities were established for the effective use of these facilities.

The net water output of source facilities was estimated by the operation study for development plans with various combinations of source facilities.

In addition, a monitoring system was proposed in Section 6 to identify water deficit for the operation of source facilities.

After submission of the Draft Final Report in January 1985, the Study Team received comments on the industrial water demand of the State of Pulau Pinang and the minor irrigation water demand in the Region. The water demand and supply balance was reviewed on the basis of the revised water demand in Section 7.

In Section 8, Alternatives of interbasin transfer plan from the Muda to Kedah river basins are evaluated from the viewpoint of risk of water shortage expected to remain in these two basins.

In Section 9, the cause of water deficit in the integrated river system was analyzed for the use of economic evaluation of the Beris dam as well as overall development plans.

2. RIVER SYSTEMS AND SOURCE FACILITIES

2.1 River Basin Model

The river basin models schematically illustrated in Plates 1 and 2 are reproductions of those used for Part 1 Study. The model for Part 2 Study is principally the same as used for Part 1 Study, but the Perlis, Rui and Juru and southern rivers are excluded from Part 2 Study because they are isolated from the integrated Kedah - Muda - Perai river system in which the output of the Beris dam is utilized. The Arau and Gial rivers are also excluded because the river water is consumed by small irrigation schemes along their river courses and scarcely contribute to the MADA area.

The MADA irrigation area is the largest water user in the integrated Kedah - Muda - Perai river system. At present, the main water sources to the area are the uncontrolled flow of the Kedah river and the controlled flow from the Pedu - Muda dam system. The supply capacity is, however, not sufficient to guarantee the demand in dry years under the present condition.

On the other hand, the Muda river has abundant water throughout the year except a few months a year. The excess water is transferable at Jeniang site in the middle reaches of the Muda river to the MADA area by constructing an intake weir across the main river and a diversion canal.

With the Jeniang transfer system, uncontrolled river flow of the Muda river and the controlled flow by the proposed Beris dam can be diverted to the MADA area.

In this study, water demand and supply balance and operation studies of source facilities are carried out for the integrated Kedah - Muda - Perai river system.

2.2 Source Facilities

The following source facilities were incorporated in the water demand and supply balance and integrated operation studies.

(1) Existing source facilities

- Muda dam
- Pedu dam
- Ayer Hitam dam
- Pelubang barrage
- Kedah barrage
- Muda barrage
- Perai barrage

Table 1 summarizes the principal features of these existing facilities.

(2) Ongoing projects

- Ahning dam in the Kedah river
- Mengkuang dam in the Perai river
- Jeniang transfer system with Naok dam and a double way canal to Pelubang

The principal features are summarized in Tables 2 and 3.

(3) Proposed Beris dam

The Beris dam is proposed on the Beris river, one of tributaries of the Muda river. The damsite is located 1.6 km upstream of the confluence of the Beris and Muda rivers. The project features are shown in Table 4.

(4) Other potential facilities

The effects of the following projects are examined as the potential projects after the Beris dam project.

- Tawar - Muda dam
- Reman dam, pumped-storage scheme
- Merbok storage scheme
- Khlong Thepha dam

Table 5 shows the principal features of these potential projects.

3. UPDATED SUPPLY AND DEMAND DATA

3.1 River Runoff

In Part 1 Study, the daily river runoff was estimated at the key stations selected for each river system for the 20-year period from 1961 to 1980.

For the feasibility study of the Beris dam (Part 2 Study), the study area was limited to the Kedah, Muda and Perai river systems which are to be integrated each other after the Jeniang system is implemented. The rivers in Pinang island are involved in the Perai river system. The river runoff data of these three river systems were extended for 3 years up to the end of 1983 as described in Annex E, Hydrological study for Part 2 Study.

The natural runoff is defined as the runoff which is not significantly affected by water withdrawals in the catchment area. The runoff data at the key stations are tabulated in Tables 5 to 13 in the above-mentioned Annex E, for the 23-year period on the 5-day basis. Table 6 summarizes the annual runoff volume at the key stations for the 23-year period.

For the purpose of estimating river runoff at an arbitrary location in a river basin, the river basin was further divided into 3 to 7 sub-basins as shown in Fig. 1. The 5-day runoff data of a sub-basin of a river basin is transposed from the key station of the river basin assuming that the average rainfall loss is distributed evenly in the river basin. Furthermore, runoff depth at an arbitrary location in a sub-basin is assumed to be uniform over the sub-basin.

The annual natural runoff at major source facilities of the Kedah - Muda - Perai river system is summarized in Table 7. The total available water resources of the river systems are $2,156 \times 10^6$ m^3 in the Kedah river, $3,313 \times 10^6$ m^3 in the Muda river and 438×10^6 m^3 in the Perai river on the average of the 23-year, which are counted at the lowest point of the main stream for the balance calculation, i.e. at the Kedah barrage including the Muda - Pedu catchment in the Kedah river, at the Muda barrage in the Muda river and at the Perai barrage in the Perai river (Ref. to Table 17 in Annex E, Part 1 Study).

3.2 Water Demand

3.2.1 Demand projection

There are three types of water demand assumed for the Kedah - Muda - Perai river system: domestic and industrial water demand, irrigation water demand and river maintenance flow.

Although the future domestic and industrial water demand was estimated for two cases of projection of the regional population and economic growth for Part 1 Study, the projection was narrowed down to one single projection for Part 2 Study based on the Mid-Term Review of Fourth Malaysia Plan (4MP), which was published in April 1984, and other information collected during Part 2 Study. The target years of the projection of water demand for the balance study are 1983, 1990 and 2000.

It is assumed that the domestic and industrial water demand is constant throughout the year. On the other hand, the irrigation water demand for the major schemes is estimated on 5-day basis under the 23-year meteoro-hydrological conditions.

Table 8 shows the summary of the average annual water demand 1983, 1990 and 2000 projection.

3.2.2 Domestic and industrial water demand

The domestic and industrial water demand for Part 2 Study is estimated in Annex B "Domestic and Industrial Water Supply".

Table 9 shows the annual water demand by intake of the balance model. The total demand of the Region is 164 x 10^6 m^3 in 1983, 311 x 10^6 m^3 in 1990 and 625 x 10^6 m^3 in 2000. This projection is slightly smaller than that for High Growth Case for Part 1 Study.

The demand indicated at intake No. 20 in Table 9 is the total demand supplied by the Sungai Dua water supply system covering most of the State of Pulau Pinang including Seberang Perai and Pulau Pinang. The actual intake volume at the intake is, however, the above-mentioned demand less the supply by natural runoff of rivers in Pinang island and the Perai river and the regulated runoff of Ayer Hitam dam. The annual abstraction volume at the intake is calculated in the Section 4.2.3.

3.2.3 Irrigation water demand

The irrigation water demand in the Region is estimated in Annex D "Irrigation Development".

In Part 1 Study, a scheduled annual pattern of water demand was assigned for each intake and it was assumed that the demand was not adjusted by information of field water conditions. Then the annual demand pattern at an intake was unchanged for the 20-year simulation period. The same demand projection as Part 1 Study is applied for Part 2 Study except for MADA and its fringe area. Tables 10 to 15 show the annual water demand of the minor irrigation schemes by river system which are reproductions of Part 1 Study, though some schemes were canceled according to the information of State DID.

On the other hand, for the MADA irrigation scheme including its fringe area depending on the MADA canal, it is assumed in Part 2 Study that the water demand can be adjusted by observation of water depth of paddy field at every 7-day interval. According to the proposed irrigation method given in Annex D, a plot-to-plot model was constructed to simulate a field water condition of an irrigation service unit below an offtake of the MADA tertiary canal system. At the beginning of every 7-day interval, a scheduled amount of irrigation water is taken at the offtake if the water depth of the lowest plot is lower than a critical depth assigned in advance but no water is taken if the field water level is higher than the critical depth. A daily water balance of the plot-to-plot model is calculated taking into account daily rainfall on the irrigation unit.

The resulting irrigation water demand of MADA area accumulated at the Pelubang intake is compiled on 5-day basis for the water balance calculation for the meteorological conditions of 1961-1983 period and it is summarized in Tables 16, 17 and 18 for 1983, 1990 and 2000 demand projections, respectively on monthly basis.

3.2.4 River maintenance flow

As assumed in Part 1 Study, river maintenance flow is necessary to sustain water quality of the Kedah river water. The minimum rate of discharge downstream of Alor Setar to maintain BOD concentration below 10 mg/l is estimated at 2.7 m^3/s in 1990 and 5.9 m^3/s in 2000 under the condition that sewerage development and improvement of purification system are implemented as proposed in Part 1 Study.

If the sewerage development will not be implemented, the minimum discharge shall be 17.0 m^3/s in 2000. Table 19 summarizes the requirement of maintenance flow.

In the balance calculation, it is assumed that the river low flow downstream of Alor Setar is argumented up to the above-mentioned requirement of maintenance flow under the condition with sewerage development and purification improvement in 1990 and 2000 by means of release from dam storage.

4. WATER DEMAND AND SUPPLY BALANCE WITH UNCONTROLLED RIVER RUNOFF

4.1 Water Demand and Supply Balance Model

In the first step of the analysis, the water demand and supply balance with uncontrolled river flow was calculated for each river system. The calculation model of a river system and calculation procedure are the same as those used for Part 1 Study. The model consists of tributary models and main stream models. It is defined that a main stream is a river stretch upstream of which source facilities are assumed. The tributary model calculates deficits at all the intakes in the tributary in which no source facilities are assumed and surplus runoff volume running into the main stream on 5-day basis.

The main stream model divides the river course into several stretches and calculates balance of each stretch. Runoff inputs for the main stream model are the discharge from tributaries, the natural flow from the own catchment area of the main stream and return flow from outlets along the specified main river stretch.

Figs. 2 and 3 illustrates a simplified tributary model and a main stream model, respectively, which are reproductions of those for Part 1 Study.

(1) Kedah river model

The Kedah river model consists of one main stream model and 14 tributary models, of which 4 rivers are flowing into the MADA irrigation area. The main stream model of the Kedah river starts from the Pedu dam and ends at the Kedah barrage. The main river course is divided into 28 stretches. A balance in the MADA irrigation area, which is fed mostly by the Kedah main stream through the MADA canal system is calculated by a model specified for the area. A detailed discussions of the MADA irrigation model is given in Annex D "Irrigation Development".

(2) Muda - Perai river model

The Muda - Perai river model consists of one main stream model and 11 tributary models in the Muda river and 3 tributary models in the Perai river. The tributaries in the Perai river are connected with the main stream model by the Pinang Tungal irrigation canal and Sg. Dua canal for D & I water supply which also connects with small rivers in Pinang island. D & I water supply demand in the State of Pulau Pinang mostly occurs along the Sg. Muda canal system.

4.2 Water Deficit

4.2.1 General

Water demand and supply balance calculation was carried out for water demand of 1983, 1990 and 2000 of target years under the hydrological condition in the period from 1961 to 1983 on 5-day basis.

4.2.2 Water demand and supply balance in tributaries

Table 20 shows annual water deficit by tributary basin in terms of average annual deficit, maximum annual deficit and number of deficit years.

4.2.3 Water balance in main stream

(1) Kedah river system

Figures 4 to 6 illustrate the balance of water demand and uncontrolled flow at the lowest intake near Alor Setar on 5-day basis for 1983, 1990 and 2000.

Tables 21 to 23 show the water deficit along the main stream of the Kedah river estimated for 1983, 1990 and 2000 compiled on the monthly basis.

These tables show the balance with uncontrolled flow, but the outflow of the Pedu - Muda dam is not counted.

The deficit for 1983 demand is estimated at 1,087 x 10^6 m^3 on an average and the water deficit for future demand is estimated at 1,072 x 10^6 m^3 for 1990 and 1,115 x 10^6 m^3 for 2000, respectively on an average under the 23 years hydrological condition, in which the release from the Pedu dam is not counted.

As discussed in the following Section, the effect of the Pedu - Muda dam is estimated at about 690 x 10^6 m^3 on an average, it is roughly estimated that off-season crop in the MADA area can be caltivated on only 55% of the total irrigation area under the 1983 water demand condition.

(2) Muda - Perai river system

The Muda river is integrated with the Perai river by the Pinang Tungal canal for irrigation purpose and also with the Perai river and local rivers in Pinang island for water supply purpose. The abstraction volume from the Muda river for these systems is given as the water deficit arising in the canal systems, which is the demand less natural runoff supply by the Perai and the local rivers. Tables 24 to 26 show the annual abstraction volume for the Pinang Tungal system and Tables 27 to 29 show that at intake 20 in the demand and supply diagram (Plate 2) for Pulau Pinang water supply.

The total annual deficit accumulated along the main stream of the Muda river is shown in Tables 30 to 32 for 1983, 1990 and 2000, respectively. The water deficit occurs 8 times during the 23-year period for 1983 demand. The average annual deficit is calculated at 7 x 10^6 m^3 for 1983 demand and it will increase to 19 x 10^6 m^3 in 1990 and 43 x 10^6 m^3 in 2000. Although the average deficit is low even in 2000, a deficit bigger than 100 x 10^6 m^3 occurs 5 times during the 23-year period.

Figures 7, 8 and 9 illustrates the balance of water demand (withdrawal from the Muda river) and uncontrolled flow at the Muda barrage for 1983, 1990 and 2000.

4.2.4 Effects of Ayer Hitam and Mengkuang dams

The storage of the Ayer Hitam dam is 2 x 10^6 m^3 and the effect was counted in the process of the above-mentioned water balance of the Pulau Pinang water supply system.

The Mengkuang dam is under construction also for the Pulau Pinang water supply system.

During the wet season, the excess water of the Kulim river and the Muda river is pumped up into the Mengkuang reservoir of 24 x 10^6 m^3 in effective storage capacity. The storage water is released when a water shortage occurs in the water supply system(Ref. F 1).

The output of the Mengkuang dam was simulated on 5-day basis for the 23 years hydrological condition. The resulting average annual output was 2 x 10^6 m^3 for 1983, 6 x 10^6 m^3 for 1990 and 14 x 10^6 m^3 for 2000 demand. Tables 33 to 35 shows the release of Mengkuang dam on monthly basis for 1983, 1990 and 2000 demand conditions.

Because the water deficit in the wet year is estimated to be less than the supply capacity of the Mengkuang dam even for 2000 demand, the storage will not be fully utilized every year. On the other hand, the dam is effectively utilized in drought years and the maximum annual output was estimated at 33 x 10^6 m^3 under 1979 hydrological condition for 2000 demand.

Tables 36 to 38 show the remaining water deficit in the Muda river under the condition with the Mengkuang dam.

5. OPERATION OF INTEGRATED RIVER SYSTEM

5.1 Objectives

The Kedah river system and the Muda - Perai river system are connected each other after the Jeniang transfer system is implemented. In this study, a simulation model is constructed to examine the behavior of source facilities in the integrated Kedah - Muda - Perai river system for various combinations of source facilities. The model is hereinafter called as the integrated operation system. The source facilities incorporated in the system are operated simultaneously at 5-day intervals under the 23-year hydrological condition.

Figure 10 schematically illustrates the integrated operation model in which all the assumed source facilities are involved.

The objective of the study is to establish integrated operation rules of the source facilities for the purposes of (1) minimizing the spillout from reservoirs so as to utilize the stored water to the maximum extent and (2) minimizing damages caused by shortage of supply if the supply capacity of the integrated operation system is insufficient.

The appropriate operation rules are obtained by the trial and errors method. The outputs of source facilities derived from the simulation model by applying the recommended operation rules are used for the economic evaluation of the Beris dam and overall plans of source facilities.

5.2 Cases of Jeniang Weir Operation

The Muda river water collected at the proposed Jeniang weir site, including the uncontrolled flow and the controlled flow of the Beris dam, can be diverted to the MADA irrigation area through the transfer canal of the Jeniang system. The rate of the diversion water depends on the operation rule of the Jeniang weir. In this section the following three cases of the operation rule are preliminarily examined for consideration by the decision-makers. These are referred as Cases.

Case 1 : Water demand along the Muda river has the priority to use the water collected at Jeniang. The water deficit to be met in the Muda river will, however, occur once in a few years even in 2000. Then the excess water can be diverted to the MADA area.

Case 2 : An intermediate plan between Case 1 and Case 3 to distribute the water deficit both to the Kedah and the Muda - Perai river systems.

Case 3 : The Muda river water can be diverted to the MADA irrigation area through the Jeniang system to the extent not to cause any increase of water deficit in the Muda main stream compared with the future deficit without the Jeniang project.

As the combinations of source facilities, the following sequence of project implementation was assumed. These are referred as Combinations.

For 1983 demand:

(a) Pedu - Muda dam

For 1990 and 2000 demands:

(b) Pedu - Muda dam + Ahning dam

(c) (b) + Jeniang system

(d) (c) + Beris dam

The Combinations of (b), (c) and (d) were examined for three Cases.

The potential projects were assumed to be implemented after the Beris dam. The following cases of alternative combinations were selected in this study.

(e) (d) + Reman dam

(f) (d) + Tawar - Muda dam

(g) (d) + Khlong Thepha dam

(h) (d) + Reman dam + Tawar - Muda dam

(i) (d) + Reman dam + Tawar - Muda dam + Khlong Thepha dam

These Combinations were examined for Case 1 and Case 3.

The deficit in the Muda river was assumed to be partially removed by the output of the Beris dam in Cases 2 and 3. The remaining deficit in the Muda river for these Cases shall be removed by the output of the Merbok storage. Thus the effect of the Merbok storage was examined for these Cases while the storage is not necessary for Case 1.

5.3 Calculation Procedure

5.3.1 Water deficits at Pelubang and Jeniang sites

There are two balance points in the operation system. One is the Pelubang barrage site in the Kedah river and the other is the Jeniang weir site in the Muda river. Source facilities in the operation system are operated for the water deficits identified at these balance points.

(1) Water balance at Pelubang barrage

The water demand and available water at the Pelubang site are the same as those used for the main stream model of the uncontrolled flow balance as described in the previous Section 4.

For the condition without the Jeniang system, the water taken at the Pelubang site is distributed evenly over the MADA irrigation area including the main and fringe areas.

On the other hand, for the condition with the Jeniang system, it is assumed that the water taken at the Pelubang site is sent firstly to the northern MADA area which is fed by the MADA northern and central canals for the effective use of the Muda uncontrolled flow in the MADA area.

If the Kedah river water can fulfill all the demand in the northern area, the excess water of the Kedah river, if any, is sent to the sourthern MADA area of 33,400 ha which is fed by the MADA sourthern canal.

(2) Water balance at Jeniang weir

The water demand at the Jeniang weir comprises the demand arising along the Muda main river downstream of Jeniang and the remaining deficit in the MADA irrigation area, if the Jeniang system is in operation.

The demand in the Muda downstream area is given as the result of the water balance calculation of the Muda main stream model with Mengkuang dam as described in the previous Section 4.

The effects of the operation of the Jeniang weir to the water balance in the Muda downstream were examined for operation rules of three Cases.

For Case 1, no restriction is made for releasing water over the Jeniang weir to meet the downstream water deficit in the Muda main stream. But in an extreme drought period when the reservoir water level of the Pedu dam is lower than a certain water level, water rationing is required for both Kedah and Muda river basins. On the other hand, the ceiling discharge over the Jeniang weir to meet the downstream water deficit is set for Case 2 and Case 3. Table 39 shows the relation between the rate of release (constant discharge) over the Jeniang weir and the resulted remaining water deficit in the Muda main stream. As shown in the table, the average annual deficit expected under the condition without the Jeniang system can be maintained if the constant rate of 2.5 m^3/s is released. Thus the ceiling discharge for Case 3 is set to be 2.5 m^3/s. For Case 2, the ceiling discharge is set to be 6 m^3/s as an intermediate case between Case 1 and Case 3.

The excess water at the Jeniang weir after releasing over the weir to the Muda downstream can be taken and sent to the MADA irrigation area through the transfer and conveyance canals.

If the diverted water can fulfill the demand in the southern MADA area and there is remaining deficit in the northern MADA area, the excess water, if any, is sent to the northern MADA area through a double way canal to be constructed by improving the existing central main canal.

If there is still excess water at Jeniang site, it is stored in the Naok reservoir, and the Reman reservoir if it is involved.

5.3.2 *Controlled flow balance*

The source facilities assumed in the operation model are operated to meet the water deficit remaining in the balance of uncontrolled flow. The deficits calculated at the balance points were increased by 10% taking into account a conveyance loss and a loss due to operational time-lag between the damsite and the balance point. The procedure of operation of the source facilities are described below.

(1) Reservoir water balance

The water balance of a reservoir during a 5-day period is given by the following equation:

$$Se = Sb + I - O - E - SP$$

where,

Se : Reservoir storage at the end of the 5-day period

Sb : Reservoir storage at the beginning of the period

I : Inflow to the reservoir and rainfall on the reservoir during the period

O : Outflow from the reservoir during the period, not exceeding downstream deficit

E : Evaporation from the reservoir surface during the period

SP : Spillout discharge during the period

In the case of Pedu - Muda dam system, these two dams are connected by the Saiong diversion tunnel. The water stored in the Muda reservoir is sent to the Pedu reservoir through the tunnel and the regulated water is released from the Pedu dam in normal operation.

The detailed procedure of a reservoir water balance calculation and input data such as stage-storage curves, evaporation rate and rainfall and inflow data are described in Annex I of Part 1 Study.

(2) Discharge capacity

Two sets of discharge valves are provided with each dam. Table 40 summarizes the maximum capacity of the valves at the low water level.

In the case of the Pedu dam, the stage-capacity curve of the valves is given in Table 41 (Ref. F 2).

(3) Initial conditions

Since the storage of the Pedu - Muda and Ahning dams have storage capacities carried over several years, the initial setting of the reservoir water level would affect the results of the water output of the system.

In this study, the simulation study was carried out for two cycles of the 23-year period. For the first cycle, the calculation started at the reservoir full condition. The reservoir water levels at the end of the first cycle was used as the initial conditions of the second cycle. Then all the outputs of the simulation study were obtained from the results of the second cycle.

(4) Shutdown effect of dam

If a dam project is assumed in the operation system, the catchment water of the damsite is shut down at the site.

The shutdown discharge was estimated for the Anhing dam in Kedah river, and the Beris and Tawar - Muda dams for two cases, i.e. they are operated for the Muda river system and for the Kedah river system through the Jeniang system as shown in Table 42.

(5) Operation sequence

The integrated operation system was operated under the conditions without operation rules and with operation rules for the purpose of examining the effects of the operation rules of source facilities.

For the case of "without operation rules", source facilities assumed in the system were operated so as to fully remove the deficit arising at the balance points of Pelubang and Jeniang sites at 5-day interval as far as the storage of reservoirs allows. The maximum release from a reservoir is restricted by the capacity of discharge valves. If the water level of any reservoir reaches to the low water level, release from the reservoir is limited to the rate of inflow discharge.

In the case of "with operation rules", release from a reservoir is determined according to the operation rules to be established in the following section.

5.4 Behavior of Source Facilities under the Condition Without Operation Rules

Figure 11 shows the resulting release from the Pedu dam together with the total deficit at the Pelubang site for the 23-year period under the condition without operation rules for 1983 demand. The shadowed area indicates the remaining deficit left after the release from the dam. Since the regulated output of the Pedu dam is insufficient except in wet years to meet the deficit, the remaining deficit is concentrated in the later part of the period in the off-season cropping, usually between June and August. If the Jeniang system and the Beris dam are implemented, the total deficit can be decreased by some 250×10^6 m^3 or 63% of the above-mentioned remaining deficit in 2000. But the situation that the remaining deficit is concentrated in a few months cannot be improved, if the reservoirs are operated under the condition without operation rules as shown in Fig. 12 in which the total output of the Pedu, Anhing and Beris dams and the Jeniang system is illustrated.

Because more than 90% of the proportion of the remaining deficit to the total demand on 5-day basis continues for a few months in dry years, off-season crop production would be remarkably decreased and shortage of D & I water supply would be serious. Thus operation rules to avoid the concentration of deficit are indispensable for the situation that the total supply capacity of source facilities are insufficient to remove the water deficit. But the case without operation rules herein described was worked out for the purpose to demonstrate the effects of the case with operation rules.

5.5 Operation Rules

5.5.1 General

Operation rules of the integrated operation system are prepared for the purpose (1) to minimize the total spillout volume in the system, and (2) to disperse the remaining deficit as much as possible if the total supply capacity is insufficient. In the following section, operation rules for these two objectives are discussed and they are combined in recommended operation rules which were obtained by trial operations of the simulation model

5.5.2 Operation rules for minimizing spillout

The Pedu - Muda dam has a predominant scale of storage which can regulate seasonal and yearly variation of demand and, therefore, the subordinate reservoirs are effectively operated by applying appropriate sequences of release and discharge patterns of the reservoirs based on information of inflow and size of reservoirs.

Table 43 shows the active storage, average annual inflow and the proportion of the active storage to the annual inflow.

The Pedu - Muda dam is characterized by its predominantly large storage capacity, occupying 80% of the total active storage of three dams including the Pedu - Muda, Ahning and Beris dams. The storage capacity is 1.5 times the average annual inflow. It was estimated that about 600×10^6 m^3 of storage is necessary for the within-year regulation and the remainder of 450×10^6 m^3 is used for carry-over storage of long term operation.

The Ahning reservoir is a strategic reservoir which can completely regulate the inflow by its storage capacity of 200×10^6 m^3, which is about 3 times the average annual inflow volume. The purposes of the dam are water supply and hydropower generation. The D & I water supply demand depending on the dam is estimated at 3 m^3/s at maximum (Ref. F 4). Relatively constant outflow is required for these purposes.

The active storage of the Beris dam is almost equal to the average annual inflow. The reservoir can be classified as the within-year storage. It is, therefore, understood that the reservoir should be emptied before the wet season comes as far as the discharge capacity of outlet valves allows.

Tawar - Muda dam is also of the within-year storage. The storage is relatively small compared with the annual inflow volume.

The Reman dam is a pumped-storage scheme and the available runoff is sufficient to fill the storage of 240×10^6 m^3 (Ref. F 5).

The Khlong Thepha dam is planned in Thailand and the regulated outflow is diverted to the Pedu river upstream of the Pedu dam. The regulated outflow is expected to be 73×10^6 m^3 and it is regulated again by the Pedu reservoir.

5.5.3 Proposed sequence of release

Based on the above-mentioned consideration, the following sequence of release and discharge pattern were worked out by simulation studies.

The Ahning dam should be operated to release a constant outflow of 3 m^3/s throughout the year if there is water deficit at the Pelubang barrage. Because the storage of the Ahning reservoir is not fully utilized by the above release, the release is increased up to 5 m^3/s if the supply capacity of the system is insufficient, judging from the reservoir water level of the Pedu dam being lower than El. 90 m.

The target deficit of the Beris dam is the deficit unsatisfied by the Ahning dam. The Beris dam is operated to supply water for the peaking period of the deficit by its release capacity of 15 m^3/s at maximum, which was determined so as to use the fully capacity during the peak demand period from February to April, but the release is restricted to 5 m^3/s if the Beris reservoir water level is lower than El. 75 m to avoid reservoir water level staying at the low water level for a long period.

If the Reman storage is involved, the excess water of the Muda river at the Jeniang site is pumped up whenever it is unfilled. The release from the reservoir is made until the remaining deficit is removed, but the release is restricted by 40 m^3/s of the capacity of transfer canal of the Jeniang system.

For the Combination of the Beris dam plus the Tawar - Muda dam, the simulation study shows that there is no difference in the net water output whether the release of the Beris dam comes first or next to that of the Tawar - Muda dam.

If the Merbok storage is implemented, the deficit in the Muda river can be completely removed and the storage can be operated separately from the integrated operation system. The storage requirement and the effect are discussed in the following Section 5.5.7.

The Khlong Thepha dam is also operated separately from the integrated system. Since the release from the reservoir is regulated by the Pedu dam, the operation rule is simply to send the stored water constantly to the Pedu dam.

For Case 1 Muda priority case, the deficit in the Muda downstream may be larger than the possible release from the Beris dam, or the Beris plus other dams. The situation could be overcome by emergency release from the Muda dam whose discharge capacity is sufficient to remove the deficit. The net water output from the Muda dam is regarded as being traded off by the output of the Beris dam.

The Pedu dam is operated to remove the total water deficit deducted by the releases of the other source facilities. The Pedu dam can meet all the seasonal as well as yearly variations of the remaining deficit by its large storage capacity. The supply capacity is, however, insufficient in dry years in most of the Combinations of source facilities. The operation of the Pedu dam when the supply capacity is insufficient is discussed in the next Section.

5.5.4 Operation rules for insufficient supply condition

Under the insufficient supply condition, the water demand of the system should be reduced to the extent not to empty the Pedu dam.

The seasonal pattern of the water deficit in the Kedah river is that the deficit is concentrated in February to April and the reservoir water level of the Pedu dam is highest usually at the beginning of February. Thus the water level at the beginning of February can be an index to evaluate the possible output of the dam. The net water output of a year was examined for various cases of the initial reservoir water level for the 23 years demand condition, assuming the storage is fully utilized within the year. Fig. 13 shows the relation between the initial water level at the beginning of February and the proportion of the net water output to the total water deficit at Pelubang barrage assuming that the initial storage is fully utilized within the year.

According to Fig. 13 for 1983 demand in which the Pedu dam only is assumed as a source facility in the system, the demand under 1963, 1964 and 1977 cannot be fulfilled even if the initial water level is set at the high water level of El. 97.5 m. On the other hand, 100% of demand can be satisfied in wet years of 1967 and 1973 if the initial water level is set above El. 90 m.

Figure 13 also shows the relationship for the case that the system with source facilities of the Pedu - Muda, Ahning and Beris dam and the Jeniang system is operated for Case 3 under the 2000 demand, (Kedah priority allocation). Even if these source facilities are involved, the water deficit under 1963 and 1977 cannot be fully removed at any initial water level, but the proportion of the net water output to the total demand increases by 5 to 15% compared with the case of Pedu - Muda dam only.

5.5.5 Proposed operation rules of Pedu dam

The off-season crop schedule is commenced at the beginning of February and ends in August. As discussed in the previous section the water level of the Pedu dam can be an index of the rate of reduction of supply. Since the water demand for the off-season crop of the MADA irrigation area is predominant in the operation system, the reduction of the demand can be effectively achieved by adjusting the off-season MADA demand.

Thus it was assumed that the irrigable area for off-season crop of the MADA irrigation system is determined for each year referring to the water level of the Pedu dam on the first of February. In addition, in a very dry year like 1963 and 1977, the irrigable area cannot be assured by 100% even the initial water level is set at the high water level. For these years, a supplemental rule was introduced, in which the supply is cut by 20%. This value is depending on the combination of source facilities judging from the water level on the first of April if the drawdown of the reservoir since the first of March is larger than 6.5 m.

In spite of the above reduction of demand, the reservoir might be emptied for a long period in drought years. To cope with this situation, it was assumed that all the demand be cut evenly if the reservoir water level lower below El. 75 m by a reduction rate of 10% and further below El. 72 m by 20%.

5.5.6 Summary of proposed operation rules

The appropriate operation rules were worked out for each combination of source facilities by trials and errors method so as to maximize the total water output of the system under the condition that the Pedu dam is allowed to be emptied only once during the 23-year operation period and the emptied duration is less than one month.

The propsed operation procedures are illustrated in Fig. 14 and the operation rules for Combinations are summarized in Table 44. The results of the operation and the behavior of the system are discussed in Section 5.6.

5.5.7 Operation of Merbok storage

There is a lot of excess water in the downstream reaches of the Muda river even in the 2000 demand condition. The excess water is planned to be stored in a pond created in a mangrove swamp situated at the coastal area between the Muda and the Merbok rivers. The stored water is pumped up back to the Muda river when water deficit occurs along the pond above the Muda barrage, usually in February to April.

The deficit expected in 2000 depends on the operation rule of the Jeniang weir. If the release from the Jeniang weir is limited at 2.5 m^3/s; Case 3 the annual deficit is 122×10^6 m^3 at maximum. In the case that the ceiling of the Jeniang release is 6 m^3/s; Case 2, the maximum annual deficit would be 80×10^6 m^3. The target water deficit is illustrated in Figs. 15

and 16 for 1990 and 2000 for Case 2 and in Figs. 17 and 18 for 1990 and 2000 for Case 3 respectively.

Two alternatives of the Merbok in size were prepared to meet the above requirements. The size (A) plan for Case 3 has a net storage capacity of 133×10^6 m^3 while the size (B) plan for Case 2 has a net capacity of 83×10^6 m^3.

Because the water deficit is usually low in the Muda river except a few years, the average annual net water output is 12×10^6 m^3 in 1990 and 29×10^6 m^3 in 2000 for Case 3, and 7×10^6 m^3 in 1990 and 19×10^6 m^3 in 2000 for Case 2.

Thus the Merbok storage can remove all the deficit in the downstream area of the Muda river, but the project might not be economically justified under the water deficit up to 2000.

5.6 Net Water Output of Source Facilities

5.6.1 General

Annual water balance of the operation system is summarized in Tables 45 to 62 for all the Combinations of source facilities assumed in this study. The calculation procedure is herein explained according to column number in Tables 45 to 62.

(A) Release requirement to the Muda river at Jeniang. The maximum discharge differs with Cases of Jeniang operation rule and the minimum is 2 m^3/s.

(B) Demand along the Kedah main stream + northern MADA area + maintenance flow of the Kedah river. If the Pedu reservoir is operated following to the proposed operation rules, the demand in MADA area indicated here is the reduced demand by applying the ratio of demand cut shown in column (Q).

(C) Demand in southern MADA area: It is also affected by the ratio of demand cut if operation rule is applied.

(D) Withdrawal from the uncontrolled flow of the Kedah river at and below the Pelubang barrage.

(E) Water deficit in northern MADA area.

(F) Withdrawal from the uncontrolled flow of the Muda river at the Jeniang weir.

(G) Release from the Naok reservoir to the MADA area.

(H) Release from the Reman dam.

(I) Release of the uncontrolled flow from the Jeniang weir to the Muda river.

(J) Deficit in the southern MADA area. If the Beris dam is assumed, supply requirement of the Muda main stream is added, which is given as (A) - (I).

(K) Total deficit: (E) + (J) divided by 0.9 of operation and conveyance efficiency.

(L) Release from the Pedu dam: in case that the Khlong Thepha dam is assumed the output is put into to the Pedu dam and, therefore, the release of the Pedu dam is affected.

(M) Release from the Ahning dam.

(N) Release from the Beris dam.

(O) Release from the Tawar - Muda dam.

(P) Remaining deficit: The amount which is not supplied according to the operation rule when the reservoir water level of the Pedu dam is lower than El. 75 m or the drawdown of the reservoir water level during March exceeds 6.5 m.

(Q) The ratio of demand cut of the off-season crop in the MADA area. The ratio is determined according to the Pedu water level on the first of February. The ratio is effective for the period from February to June.

(R) Total output of the system including uncontrolled flow: (D) + (F) + (G) + (H) + (I) plus (L) + (M) + (N) + (O) multiplied by 0.9.

The balance of total deficit and total water output of each combination is illustrated in Figs. 19 to 24.

Tables 63 to 65 show the remaining deficit, cut ratio and the total remaining deficit which is the sum of the remaining deficit in column (P) and the amount of demand cut. The total remaining deficit for three Cases for 1990 and 2000 are illustrated in Figs. 25 and 26 for Combinations (b), (c), (d) and (e).

The water output of source facilities is given as increment of the total water output in (R) of the system due to joining of the source facilities. The net water outputs of the source facilities are summarized in Tables 66 to 70 for various alternatives as discussed below.

5.6.2 Effect of the Pedu - Muda, Ahning and Mengkuang dams

The average annual net water output of the Pedu - Muda dam, the Ahning dam and the Mengkuang dam are shown in Table 66. The output of the Pedu - Muda dam is 679×10^6 m^3 and the remaining deficit was estimated at 408×10^6 m^3 for 1983 demand. For the demand in 1990 and 2000, the output of the Ahning and Mengkuang dams are available. The remaining deficits after the supply of these dams, were estimated at 358×10^6 m^3 in 1990 and

399×10^6 m^3 in 2000 for the Kedah river system and 12×10^6 m^3 in 1990 and 29×10^6 m^3 in 2000 for the Muda - Perai river system.

Figure 19 illustrates the water output of the Combination (b), Pedu-Muda dam only, for 1983 demand under the condition with the proposed operation rules. As calculated in Table 45, the supply to the MADA area is cut every year with the cut ratio of 15% to 75% depending on the reservoir water level conditions. Although the average cut ratio was as large as 45%, the concentration of deficit at the end of the off-season crop schedule was avoided and saving of supply by 20% to 30% for other purposes occurred 9 times for the 23-year period when the Pedu water level lowered below El. 75 m. It is noted that the large remaining deficit in the 1963 and 1977 in the table is due to the rapid drawdown during March and the cut ratio to the MADA area was increased by 20% after March.

Thus it is obviously found that the supply capacity of the Pedu - Muda dam is absolutely insufficient for the present command area of the irrigation system of the Kedah river basin. It is roughly said the possible irrigable area of off-season crop in the MADA area is about 55% of the total command area.

5.6.3 Net water output of the Jeniang system

The net water output of the Jeniang system was estimated at 182×10^6 m^3 in 1990 and 185×10^6 m^3 in 2000 for Case 1 and there was no difference in the output in 1990 but it was 187×10^6 m^3 , a slightly higher for Cases 2 and 3.

Figure 22 shows the total net water output of Combination (c) including the Pedu - Muda, Ahning and Mengkuang dams and the Jeniang system, for Case 1 in 2000. The remaining deficit in this system was estimated at 214×10^6 m^3 in which the average ratio of demand cut of the MADA area was 22% and the remaining deficit was 42×10^6 m^3 as shown in Table 63. The ratio of demand cut was 50% in the consecutive drought years of 1964 and 1965 while 5 years out of the 23-year could receive full supply to the demand in Kedah river system.

It is noted that the Jeniang system includes the double way canal from the Guar Kepayang to the Pelubang barrage in addition to transfer canals and the Naok dam as recommended by the Jeniang Study Team (Ref. F 6). Since the plan of double way canal is still preliminary, feasibility of the plan is not sure yet. If the canal is not involved in the system, the reduction of the net water output was estimated at 12×10^6 m^3.

5.6.4 Effect of the Beris dam

The net water output of the Beris dam was estimated at 65×10^6 m^3 in 1990 and 66×10^6 m^3 in 2000 for Case 1, 65×10^6 m^3 in 1990 and 2000 for Case 2, and 63×10^6 m^3 in 1990 and 66×10^6 m^3 in 2000 for Case 3. Thus it can be said the alternative operation rules of the Muda river at the Jeniang weir will affect little to the net water output of the Beris dam, though the allocation of the output to the Kedah and Muda river differ with the Cases as shown in Table 67. Figure 23 shows the balance of the total demand and total net water output if the Beris dam is added for 2000 demand.

For Case 3, Kedah priority, the remaining deficit after the implementation of the Beris dam was estimated at 147×10^6 m^3 in 2000. The ratio of demand cut was 13% on an average. The Beris dam could improve 8% of the ratio of demand cut which corresponds to about 7,500 ha of the MADA area for off-season crop. Although the maximum ratio of the cut was 50% in 1963 and 1964, the system can fully supply to the demand in the Kedah river for 10 years out of 23 years.

In Case 1, Muda priority, 26×10^6 m^3 or 40% of the net output was regarded to be supplied to the Muda river in 2000 and the remainder of 40×10^6 m^3 was to the Kedah river. The improvement of the cut ratio of the MADA demand was estimated at 7%. The Case 2 is located in between the above-mentioned Cases. The net water output was allocated to the Muda river by 10×10^6 m^3 and the remaining 55×10^6 m^3 was allocated to the Kedah river. The improvement of the ratio of demand cut was estimated at 6%.

5.6.5 Effects of potential dams

If the Reman dam is implemented following to the Beris dam, the demand in the Kedah river can be fully supplied for 14 years out of 23 years and the maximum ratio of demand cut was reduced to 20% for Case 3. The remaining deficit was estimated at 65×10^6 m^3 for the Kedah river and 27×10^6 m^3 or the Muda river. On the other hand, the remaining deficit for the Case 1, Muda priority, was 80×10^6 m^3 of which 77×10^6 m^3 was allocated for the Kedah river and 3×10^6 m^3 for the Muda river. Figure 24 shows the balance of the total deficit and the total water output if the Reman dam is added for Case 3.

For removing the remaining deficit, Tawar - Muda and Khlong Thepha dams are necessary but these dams cannot remove all the deficit for the 23-year period.

For Cases 2 and 3, the Merbok storage is effective. The deficit of the Muda river can be removed by the storage. However, the project might not be economically justified since the net water output of the project is 27×10^6 m^3 in 2000 with its storage capacity of 130×10^6 m^3. This is because the deficit in Muda river is far smaller than the capacity of the storage in average and wet years and the full storage is required only once several years.

If all the potential dams assumed in this study are involved, in which the Merbok storage supplies water to the Muda river deficit and the other potential dams are operated for the Kedah river deficit, the remaining deficit would be 3×10^6 m^3 in 1990 and 44×10^6 m^3 in 2000 for Kedah river and all the deficit can be removed in the Muda river.

As an optional study, the net water output of the Reman dam is calculated under the condition that the Reman dam is implemented following to the Jeniang system and the Beris dam is not involved for Case 1 in 2000. The net water output is estimated at 114×10^6 m^3 which is 17×10^6 m^3 larger than the net water output if the Reman dam is put into operation following to the Beris dam.

6. IDENTIFICATION OF WATER DEFICIT

6.1 General Procedure

For the purpose of operating the source facilities in the integrated river system, it is recommended to establish a control center who is in charge of giving instructions of operation to all the source facilities including the Pedu, Muda, Ahning, Beris dams, and the Pelubang, Jeniang, Kedah and Muda Barrages and other potential dams if they are implemented.

On the other hand, the following monitoring points shall also be established for the purpose of identifying the water deficit for which the source facilities are operated; the Pulebang 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 is selected as a monitoring point for the Muda downstream area because the major demands of the Muda river is located in the stretch between the station and the Muda barrage and it can be assumed that the intervening flow in the stretch is negligibly small. The station is located near the border of the States of Kedah and Pulau Pinang.

An appropriate communication system shall be established between the control center and 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 general procedure for the operation to be executed by the control center is as follows;

(1) Demand table: The control center shall collect the information of water demand of all the water users in the system at the beginning of every year and prepare demand tables at the monitoring points on 5-day basis for the year. The demand of off-season crop of the MADA area is, however, to be determined on the first of February and on the first of April referring to the Pedu water level. The final decision of the planting area for the off-season crop shall be made by a committee or other agencies concerned.

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

The source facilities are to be operated to sustain the river discharge to meet the above-mentioned scheduled demand at the monitoring points.

(2) 5-day operation: Instructions for the operation of source facilities shall be given every 5-day interval. The following procedure is required on the last day of the specific 5-day period for executing the operation for the next 5-day period:

(a) To estimate the uncontrolled river flow available for the period at the monitoring points selected for the system.

(b) To collect the information of water demand of the MADA area at the Pelubang barrage for the next period from the MADA office who is in charge of management of the irrigation system of the MADA area.

(c) To calculate the water deficit at the monitoring points. (Pelubang and Jeniang barrages and Victoria Estate station) for the next period.

(d) To determine the rate of release from each source facility for the next 5-day period following to the operation rules and send instructions of operation to the facility.

(e) Because of losses between the source facilities and a monitoring point, the river runoff at the monitoring point might be smaller than the target amount derived from the demand table. Release from the source facilities shall be adjusted at the second day in a specific 5-day period for Pelubang and Jeniang points and the third day for the Victoria Estate station considering time lags between the monitoring points and source facilities.

6.2 Estimate of Deficit

The water available at the demand center along the main river is a sum of the uncontrolled flow of the river and release from the source facilities located upstream of the demand center. Since uncontrolled flow in the future is unknown, it is assumed that the rate of uncontrolled flow available for a specific 5-day period is as same as that obtained in the previous period for the purpose to determine the water deficit to be supplemented by the release from the source facilities.

The uncontrolled flow at the Pelubang barrage can be calculated as the river discharge observed at the barrage less the release of the Pedu dam and the Ahning dam. Because of a time lag between the barrage and the damsites, it will take about 1 day that the runoff released from the source facilities become steady at the barrage if the valve openings of dams are adjusted at the beginning of the 5-day period. Thus the estimate of the uncontrolled flow shall be based on the discharge observed on the fourth or the last day of the 5-day period.

The uncontrolled runoff at the Jeniang site is calculated by the same procedure as that for the Pelubang barrage.

The runoff coming into the pool created by the Muda barrage is the discharge observed at the Victoria Estate hydrologic station. The intervening flow between the station and the Muda barrage can be neglected. Thus the uncontrolled flow is given as the observed river runoff less the release from the Jeniang weir. A time lag between the Jeniang and the Victoria estate is estimated at about 2 days.

The water demand at the Pelubang barrage is withdrawal to the MADA canal and release to the downstream for D&I water supply and river maintenance flow. If the BOD concentration measured at the Kedah barrage is higher than 10 mg/l, release from the barrage is required for diluting the BOD load below 10 mg/l.

The water demand at the Jeniang barrage is the withdrawal to the Jeniang system and the release to the Muda downstream. The withdrawal required for the Jeniang system is the deficit remained in the MADA area which is the demand at the Pelubang barrage less the uncontrolled flow available at the Pelubang barrage.

The demand in the MADA downstream is a sum of withdrawals along the Muda main stream from the Jeniang to the Muda barrage. Since no water deficit occurs in the stretch between the Jeniang and the Victoria Estate station, the balance of the withdrawals below the Victoria Estate station and the uncontrolled flow estimated at the station is regarded as the water deficit in the Muda downstream. It is herein assumed that the Mengkuang dam is operated for the deficit identified in the stretch below the station. Then the remaining deficit after the Mengkuang is operated is the target the priority to use the river water. If any ceiling is given for the release from the Jeniang weir to the Muda downstream by the operation rule, the release shall be restricted by the rate of ceiling. If the Merbok system is implemented, it is to be operated for the above-mentioned remaining deficit.

6.3 Monitoring System

The above-mentioned operation procedure requires the following information of source facilities and monitoring points. The information shall be observed daily but it shall be collected by the control center on the last day of a 5-day period.

(1) Dams

Facilities : The Pedu, Muda, Ahning, Beris and other potential dams if they are impelemted.

Information : Reservoir water level
Release and spill from the reservoir

Furthermore, it is recommended to observe daily data on pan evaporation at the damsite and daily rainfall at the damsite and another site in the catchment area, which are valuable for the future studies of source facilities.

(2) Pelubang and Jeniang Barrages

Information : Intake water level
Withdrawal discharge
Release to the 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 and it shall be periodically updated.

(4) Muda barrage

Information: Water level of the pool created by the barrage.
Release from the barrage to the Muda estuary.
Withdrawals by pumping stations along the pool above the barrage.

(5) Kedah barrage

Information: Release from the barrage 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.

7. DEMAND REVIEW

7.1 Demand Review

After submission of the Draft Final Report in January 1985, the Study Team received comments on the estimates of water demand. PWA requested the Study Team to review the industrial water demand of the State of Pulau Pinang since they felt that the Study Team's estimate of future industrial water demand is high and if the demand will cause water deficit, it is possible to reduce the number of water-intensive industries in the State of Pulau Pinang.

Federal DID commented that if the water deficit will not be removed for 2000 demand by the possible source facilities, irrigation water demand due to new minor irrigation projects should be reviewed and the Study Team was requested to study water demand and supply balance for the case if new minor irrigation projects will not be developed after 1983 both in the Kedah and Muda river systems.

Thus the D & I water demand of the State of Pulau Pinang is revised as discussed in Annex B assuming that the water demand of water-intensive industries will not grow after 1985. Hereinafter the D & I water demand in the previous estimate is called as the original D & I demand and the revised estimate following the PWA's comment is called as the revised D & I demand.

Table 71 shows the annual water demand in the integrated river system in which D & I water demand in the State of Pulau Pinang is revised while two cases of irrigation water demand are shown for minor irrigation projects; with new minor irrigation development (hereafter called as Case A) and without new minor irrigation development (Case B).

7.2 Revised Water Demand and Supply Balance Calculation

The balance of the water demand and uncontrolled river runoff is calculated for the revised water demand. Tables 72 and 73 shows monthly water deficit of the Kedah river basin under the condition without new minor development (Case B). Tables 74 and 75 show the water deficit of the Muda river for the revised D & I water demand and Case A irrigation water demand for 1990 and 2000, while Tables 76 and 77 show the water deficit for the revised D & I and Case B irrigation water demands for 1990 and 2000, assuming that the Mengkuang dam is in operation.

According to the results, the average annual water deficit in the Kedah river basin for Case B irrigation water demand is $1,068 \times 10^6$ m^3 for 1990 and $1,099 \times 10^6$ m^3 for 2000. The reduction of the water deficit from Case A to Case B irrigation water demand is 4×10^6 m^3 for 1990 and 15×10^6 m^3 for 2000.

In the Muda river basin the average annual water deficit is estimated at 12×10^6 m^3 for 1990 and 29×10^6 m^3 for 2000 if the D & I water demand is revised under the condition of Case A irrigation water demand. The reduction of water deficit is nil for 1990 but 6×10^6 m^3 for 2000 compared with the water deficit for the original D & I and Case A irrigation water demands. On the other hand, if the D & I and irrigation water demands are revised (revised D & I and Case B irrigation demands), the water deficit is estimated at 7×10^6 m^3 for 1990 and 12×10^6 m^3 for 2000. In this case the reduction is 5×10^6 m^3 for 1990 and 17×10^6 m^3 for 2000 compared with the water deficit for the original D & I and Case A irrigation water demands.

8. RISK STUDY AND ALTERNATIVE SETTING

8.1 Risk Indices

Since the water deficit in the integrated river system cannot be fully removed by the possible source facilities, the water demand and supply system shall be planned under the condition with certain risk of water shortage.

In this Study, it is assumed that the risk of water shortage is represented by the following three indices; (1) frequency of water deficit year, (2) average annual water deficit and (3) the maximum water deficit on monthly basis, for the 23-year period.

As discussed in Annex L "Legal and Institutional Arrangement", it is assumed that D & I water supply and tributary minor irrigation projects have priority to take river water over the irrigation projects along the main stream. Therefore the irrigation projects depending on the main stream suffer from the remaining water deficit.

The Muda river basin is characterized that the risk level of water deficit depends on the operation rule of the Jeniang weir, while in the Kedah river basin an appropriate risk level of frequency and average annual water deficit can be obtained only by adjusting the planting area of off-season crop in the MADA area because the water deficit is already high under the present condition as discussed in the previous sections.

In this study, it is assumed that the appropriate risk level of the integrated water supply system is 5/23 of frequency and 1% of proportion of average annual water deficit to the annual water demand if the risk level of water deficit is to be balanced between the Kedah and Muda river basins. The monthly maximum deficit depends on the available output of integrated source facilities. It is, however, not necessarily possible to balance three indices simultaneously between these two river basins, but an appropriate risk level should be evaluated by a combination of these three indices.

8.2 Risk Level of Alternatives

In evaluating risk level of the Muda river basin, the following three operation rules are assumed as Alternatives of operation rule. In the calculation of water deficit two cases of irrigation water demand are assumed while the revised demand is used as D & I water demand of the State of Pulau Pinang.

In Alternative 1, the water deficit in the Muda main river is fully removed by the sum of the uncontrolled runoff and the controlled runoff from the Beris dam. Because the maximum water deficit on 5-day basis in 2000 is estimated at 30 m^3/s, two units of outlet valve of the Beris dam shall be simultaneously operated but the situation would occur in February and March once in 5 years. Under the 23-year hydrological condition, it occurs twice that the Beris dam cannot fulfill the water deficit in the Muda main river because of the limitation of the available inflow. In the situation, the deficit could be removed by the release from the outlet valve of the Muda dam.

In Alternative 2, it is assumed that a certain ceiling discharge over the Jeniang weir is set for the purpose of balancing the risk level of the water supply systems between the Kedah and the Muda river basins.

For the Case A irrigation demand it is estimated that if the ceiling discharge is set at 15 m^3/s, the water shortage in the Muda main river occurs in the frequency of 5/23, the average annual deficit of 1% and the maximum monthly deficit is some 30% to the water demand of irrigation depending on the main stream. In the case of Case B irrigation demand, the same risk level is obtained if the ceiling discharge is set at 10 m^3/s.

In Alternative 3, the Jeniang weir is permitted to take water unless it increases water deficit which affects the existing and future water users beyond that otherwise takes place up to 2000 in the Muda main river. The ceiling discharge is set at 2.5 m^3/s for this Alternative and most of the output of the Beris dam is sent to the Kedah river basin.

Tables 78 and 79 summarize the indices for three Alternatives under two Cases of irrigation water demand.

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 Pedu dam.

On the basis of the operation study in the previous section, the possible off-season crop area in the MADA area is estimated for selected combinations of source facilities if frequency is set at 5/23, the proportion of average water deficit to the demand is 1% and the maximum monthly water deficit is 20% to the demand in the planted area for three Alternatives and two Cases of irrigation demand as shown in Tables 80 and 81. The average cropping area differs with Alternatives. In these tables, the percentage is indicated as a range and the smaller value corresponds to Alternative 1 and the larger value to Alternative 3 respectively.

Figures 31 to 34 show the water output released from the Beris dam for Alternatives 1 and 2. In Alternative 1, the shadowed area shows the release from the Muda dam because of the Beris dam being empty. In Alternative 2, the water deficit above 15 m^3/s will remain not to be filled. Though the remaining water deficit appears 8 times during the 23-year period, significant deficit occurs approximately 5 times if small deficits continuing less than 10 days are neglected. On the other hand, no water is sent from the Beris dam to the Muda river in Alternative 3.

8.3 Allocation of Net Water Output

The net water output of source facility for the revised water deficit is assumed to be the same as that estimated for the original water deficit in Section 5, because the reduction of water deficit due to the revision of water demand is less than 8% of the total deficit and the output of the integrated operation system is not sensitive to the variation in water demand.

Tables 82 and 83 show the net water output of source facilities and the remaining water deficit for three Alternatives for Case A and Case B.

9. ANALYSIS OF WATER DEFICIT

9.1 General

The water deficit of the integrated river system is caused by withdrawals of various water users in the system. The cause of water deficit by users was analyzed in this study and the net water outputs of the source facilities were allocated for the users based on the analysis.

9.2 Analysis of Water Deficit

Water users assumed in the operation system were classified into the following users:

For Kedah river system;

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

(2) Main minor; minor irrigation scheme depending on off take of the MADA canal and the main stream of the Kedah river, where the main stream is a river stretch upstream of which a source facility is assumed.

(3) Tributary minor; minor irrigation schemes depending on tributaries, upstream of which no source facility is assumed.

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

For Muda - Perai river system;

(1) Main minor; minor irrigation scheme depending on the main stream of the Muda - Perai river system,

(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 value for the 23-year period. The water deficit in 1983 after the output of the Pedu - Muda dam was deducted was 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 was regarded as the demand. For the future years, the incremental deficit will mostly occurs during the period when the uncontrolled river runoff has been consumed by the existing users or the incremental demand of a purpose is relatively larger than the remaining runoff. Thus it was assumed that the incremental water deficit is allocated to users in proportion to the incremental demand after 1983. In other words, the remaining river water is allocated to users in proportion to the incremental demand based on the scheduled demand conditions in 1990 and 2000.

The water deficit caused by a user affects other users along the main stream including itself if it is located along the main stream. As discussed in Annex L "Legal and Institutional Arrangement", D & I water demand has priority to take river water over the irrigation water demand. Thus, it is assumed that 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. In this analysis, the water deficit of the system is based on two Cases of water demand estimate; (1) the revised D & I and Case A irrigation water demand (with new minor irrigation projects) and (2) the revised D & I and Case B irrigation water demand (no new minor irrigation projects). Tables 84 and 85 show the resulted average annual water deficit by cause of water deficit and by area affected by water deficit, in which the net water output of the Ahning dam and the Mengkuang dam is deducted from the water deficit caused by D & I of the Kedah and Muda - Perai rivers. In the case of 1990 when the output of these dams are larger than the water deficit caused by D & I, the excess was allocated for other users.

9.3 Allocation of Water Deficit for Source Facilities

The net water output of a source facility was allocated to remove the water deficits caused by the users assumed for the facility. Table 86 shows the water users assumed for source facilities.

The purpose of the Beris dam was assumed to supply water deficit caused by Tributary minor irrigation, Main minor irrigation and D & I water supply for both the Kedah and the Muda - Perai river systems and MADA main irrigation.

Average net water output of source facilities are summarized in Tables 87 to 92 for Allocations and Combinations of source facilities.

REFERENCES

F 1. FEASIBILITY STUDY FOR PROPOSED STORAGE SCHEME, FINAL REPORT, 1979

F 2. MUDA IRRIGATION PROJECT OPERATING AND MAINTENANCE INSTRUCTIONS

F 3. DESIGN OF WATER RESOURCE SYSTEMS, A. MAASS AND OTHERS, 1962

F 4. FEASIBILITY STUDY, DESIGN AND CONSTRUCTION SUPERVISION OF THE AHNING DAM, Oct. 1982

F 5. FEASIBILITY STUDY OF REMAN RESERVOIR PROJECT, DRAFT FINAL REPORT, Nov. 1983

F 6. FEASIBILITY STUDY FOR PROPOSED JENIANG DIVERSION, NAOK RESERVOIR AND TRANSFER CANAL, DRAFT FINAL REPORT, Aug. 1983

TABLES

Table 1 PRINCIPAL FEATURES OF EXISTING SOURCE FACILITIES

(1) Dams

Name of Dam	Muda	Pedu	Ayer Hitam
River System	Muda	Kedah	Ayer Hitam
Year of Completion	1968	1969	1962
Purpose	Irrigation	Irrigation	Water supply
Reservoir			
Catchment area (km^2)	984	171	25
Surface area (km^2)	26	65	
Normal HWL (El. m)	100.6	97.6	235
LWL (El. m)	82.3	67.8	
Active storage capacity (10^6 m^3)	160	1,049	2
Dam			
Type	Concrete buttress	Rockfill	Central core earth-rock
Crest elevation (El. m)	106	101	236
Crest length (m)	250	220	219
Dam height (m)	37	61	48
Dam volume (10^3 m^3)	30	580	

(2) Barrages

Name of Barrage	Pelubang	Kedah	Muda	Perai
River System	Kedah	Kedah	Muda	Perai
Year of Completion	1969	1970	1973	1981
Purpose	Irrigation	Tidal control	Tidal control	Flood control
Gate Type	Overshot leaf gates	Roller gates	Radial gates	Double stage roller gates
Normal HWL (El. m)	7.71		4.57	

Table 2 PRINCIPAL FEATURES OF ONGOING PROJECTS (1/2)

Name of Dam	Ahning	Mengkuang
River System	Kedah	Mengkuang
Purpose	Water Supply, irrigation & power	Water supply
Reservoir		
Catchment area (km^2)	120	3.6
Surface area (km^2)	9	1.7
Normal HWL (El. m)	113	43.3
Low Water Level (El. m)	72	
Active storage capacity (10^3 m^3)	200	24
Dam		
Type	Concrete-faced Rockfill	Earthfill
Crest length (m)		792
Dam height (m)		27
Dam volume (10^6 m^3)	750	

Table 3 PRINCIPAL FEATURES OF ONGOING PROJECTS (2/2)

	Jeniang Diversion System		
	Jeniang	Naok	Double way canal
Catchment area (km^2)	667	30	
Normal HWL (El. m)	34	30	
Active storage capacity (10^6 m^3)		27	
Dam type	Concrete Barrage	Earthfill	
Dam volume (10^3 m^3)		2,160	
Canal capacity	40 m^3/s		20 m^3/s

Table 4 PRINCIPAL FEATURES OF PROPOSED BERIS DAM WITH OPTIMUM SCALE

1.	River System	: Muda
2.	Reservoir	
	Catchment area	: 116 km^2
	Annual inflow (average)	: 109.4 x $10^6 m^3$
	Maximum WL	: El. 87.7 m
	Normal HWL	: El. 85.0 m
	LWL	: El. 69.0 m
	Surface area at MWL	: 16 km^2
	Active storage capacity	: 102 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	: 59.1 x $10^3 m^3$
4.	Saddle Dam	
	Number	: 1
	Type	: Rockfill (center core)
	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	
	Tributary	: Beris
	Discharge capacity	: 15 m^3/s
7.	Investment Cost at the end of 1983 Price Level	: M$96.6 x 10^6

Table 5 PRINCIPAL FEATURES OF POTENTIAL DAMS

		Tawar Muda	Reman	Khlong Thepha	Merbok	
River system			Muda	Khlong Thepha	Merbok	
Reserivoir					(A)	(B)
Catchment area	km^2	129	32	173	Pumped-storage	
Annual inflow	10^6 m^3	123		87		
Normal HWL	El. m	77	57	125	11.5	8.0
LWL	El. m	66.5	36.5	120	2.0	2.0
Surface area	km^2	9.1	17.6	16	14	14
Active storage capacity	10^6 m^3	54	240	78	133	83
Regulated outflow (max)	10^6 m^3			73		
Dam						
Type	Main:	Rockfill	Rockfill	Rockfill	Dyke	
	Sub:		Earthfill			
Maximum height	m	34	40	50	12.5	9
Crest length	m	82	1452	600	18,700	18,700
Dam volume	10^3 m^3	281	559	800		
Transfer Canal						
Discharge capacity	m^3/s		-	5	20	
Length	km			6	5	
Pump Capacity	m^3/s		15			
Construction cost at 1983 price level	M10^6	153	84	95	210	130

Remark; 5% of price escalation a year was assumed for 1982 - 1983.

Table 6 ANNUAL RUNOFF AT KEY STATION

River Name :	Kedah	Muda	Perai
Key Station :	Lengkaus	Jeniang	Ara Kuda
C.A. (km^2) :	1,270	756	127
Year			Unit: 10^6 m^3
1961	381.5	506.9	186.5
1962	640.7	612.0	260.1
1963	337.0	797.3	191.8
1964	378.9	619.5	211.0
1965	861.3	771.8	178.0
1966	723.6	873.9	183.7
1967	953.0	769.6	217.1
1968	644.9	463.3	153.4
1969	795.1	937.0	177.9
1970	636.8	875.5	264.6
1971	1,059.1	687.0	178.8
1972	1,163.1	723.9	191.9
1973	1,054.9	710.2	201.7
1974	898.6	493.2	134.5
1975	552.8	745.3	189.7
1976	1,040.0	1,067.0	162.5
1977	438.2	590.4	155.0
1978	494.0	549.2	119.2
1979	522.2	577.4	150.4
1980	676.5	973.7	188.1
1981	370.3	538.3	161.8
1982	555.4	940.4	148.0
1983	817.9	589.3	138.0
Mean	695.5	713.6	180.2

Remarks; (1) C.A.: Catchment area.

(2) The catchment of the Jeniang station does not include Muda dam catchment area.

Table 7 ANNUAL RUNOFF VOLUME AT MAJOR FACILITIES

Facility :	Pedu Dam	Muda Dam	Ahning Dam	Beris Dam	Pelubang Barrage	Jeniang Weir
C.A. (km^2):	173	984	120	116	1,076	667
Year						Unit: 10^6 m^3
1961	47.6	525.5	35.0	77.7	328.1	447.2
1962	80.0	634.4	58.7	93.9	551.0	540.0
1963	42.1	826.5	30.9	122.3	289.8	703.4
1964	47.3	642.2	34.7	95.0	325.9	546.6
1965	107.5	800.1	78.9	118.4	740.7	680.9
1966	90.3	905.9	66.3	134.0	622.3	771.0
1967	118.9	797.8	87.3	118.0	819.6	679.0
1968	80.5	480.3	59.1	71.1	554.6	408.8
1969	99.2	971.4	72.8	143.7	683.8	826.7
1970	79.5	907.6	58.3	134.3	547.7	772.4
1971	132.2	712.2	97.0	105.4	910.8	606.1
1972	145.2	750.4	106.5	111.0	1,000.3	638.7
1973	131.7	736.2	96.6	108.9	907.2	626.6
1974	112.2	511.3	82.3	75.6	772.8	435.1
1975	69.0	772.6	50.6	114.3	475.4	657.6
1976	129.8	1,106.1	95.3	163.6	894.4	941.4
1977	54.7	612.0	40.1	90.5	376.9	520.9
1978	61.7	569.3	45.3	84.2	424.8	484.6
1979	65.2	598.6	47.8	88.6	449.1	509.4
1980	84.4	1,009.4	62.0	149.3	581.8	859.1
1981	46.2	558.0	33.9	82.6	318.5	474.9
1982	69.3	974.9	50.9	144.2	477.6	829.7
1983	102.1	610.9	74.9	90.4	703.4	519.9
Mean	86.8	739.7	63.7	109.4	598.1	629.6

Remark; C.A.: Catchment area.

Table 8 ANNUAL DEMAND

Unit: 10^6 m^3

Basin	1983 D&I	1983 Irrigation	1990 D&I	1990 Irrigation	2000 D&I	2000 Irrigation
Kedah River						
Tributaries						
(1) Upstream of Pelubang	0	2.2	0	9.0	0	20.0
(2) Temin	0.8	25.9	1.0	27.5	1.5	40.9
(3) Downstream of Pelubang	0.5	1.5	0.8	1.5	1.2	2.9
Sub-total	1.3	29.6	1.8	38.0	2.7	63.8
Main						
(4) MADA (Main)	8.7	1,309.2	16.4	1,278.0	44.5	1,242.9
(Fringe)		22.5		21.4		21.4
(5) Others	24.0	0	38.4	1.3	92.8	5.7
Sub total	32.7	1,331.7	54.8	1,300.7	137.3	1,270.0
Total	34.0	1,361.3	56.6	1,338.7	140.0	1,333.8
Muda-Perai River						
Tributaries						
(6) Muda River	9.6	30.2	10.0	66.3	14.9	99.5
(7) Perai others	1.5	7.0	3.2	6.1	9.8	10.6
Sub total	11.1	37.2	13.2	72.4	24.7	110.1
Main						
(8) Muda River	10.3	217.6	21.0	232.0	58.9	233.4
(9) Perai River	81.1	140.0	116.2	126.0	232.3	126.0
(10) Pinang Island	60.0		90.7		182.7	
Sub total	151.4	357.6	227.9	358.0	473.9	359.4
Total	162.5	394.8	241.1	430.4	498.6	469.5
Grand Total	196.5	1,756.1	297.7	1,769.1	638.6	1,803.3

Table 9 D&I WATER DEMAND BY INTAKE

Unit: 10^6 m^3

Basin	Intake No.	1983	1990	2000
Kedah				
Tributaries				
(1) Temin, Arau, Gial	2/102	0.8	1.0	1.5
(2) Others	6	0	0	0
	7	0	0	0
	10003	0.5	0.8	1.2
Sub-total		1.3	1.8	2.7
Main				
(1) MADA	1/101	4.9	9.2	26.1
	5	3.8	7.2	18.4
(2) Others	4/105	1.7	2.5	3.8
	104	0.1	0.1	0.2
	3/103/10001	19.1	30.9	81.7
	10002	3.1	4.9	7.1
Sub-total		32.7	54.8	137.3
Total		34.0	56.6	140.0
Muda-Perai				
Tributatires				
(1) Perai others	113	0.8	2.2	8.3
	114/10005	0.7	1.0	1.5
(2) Others	8	1.9	0	0
	9/108	1.1	1.4	2.0
	17	0	0	0
	18/112	0.5	0.6	1.0
	19	0.5	0.6	0.8
	110/10004	1.9	3.1	5.6
	111	1.7	2.3	3.5
	15	2.0	2.0	2.0
Sub-total		11.1	13.2	24.7
Main	16/109	9.6	17.7	53.7
	20/Perai/Pinang	141.1	206.9	415.0
	106	0.7	0.8	1.3
	107	0	2.5	3.9
Sub-total		151.4	227.9	473.9
Total		162.5	241.1	498.6
Grand Total		196.5	297.7	638.6

Remark; Refer to Table 21 in Annex B.

Table 10 PROJECTED IRRIGATION WATER DEMAND BY RIVER SYSTEM (1/6)

Unit: 10^6 m^3

River Basin	Name of Tributary	No. of Scheme	1983	1990	2000
I. Kedah River System					
I-1 Main Stream					
Kedah	(U/S of Pelubang)	(K) 126	0	0	1.3
"		(K) 127	0	0	2.3
"		(K) 128	0	0	0.8
"		(K) 77	0	1.3	1.3
	Sub-total		0	1.3	5.7
Kedah		MADA Main	1,309.2	1,278.0	1,242.9
Kedah	(Muda Northern Canal)	(K) 55 (MADA Fringe)	2.6	2.5	2.5
"	"	(K) 54 (")	3.9	3.7	3.7
"	"	(K) 45 (")	4.7	4.5	4.5
	Sub-total		11.2	10.7	10.7
Kedah	(Muda Central Canal)	(K) 56 (MADA Fringe)	0.8	0.8	0.8
"	"	(K) 32 (")	1.5	1.4	1.4
	Sub-total		2.3	2.2	2.2
Kedah	(Muda Southern Canal)	(K) 36 (MADA Fringe)	3.1	2.9	2.9
"	"	(K) 39 (")	5.9	5.6	5.6
	Sub-total		9.0	8.5	8.5
Total of I-1			1,331.7	1,300.7	1,270.0
I-2 Tributary					
Kedah	Sg. Kesai	(K) 98	0	0	0.3
Kedah	Sg. Tok-Khamis	(K) 99	0	0	0.3
Kedah	Sg. Tekai	(K) 100	0	0	0.3
"	"	(K) 101	0	0	0.5
"	"	(K) 102	0	0	0.4
"	"	(K) 103	0	0	0.3
"	"	(K) 104	0	0	0.5
"	"	(K) 68	0	0.5	0.5
"	"	(K) 69	0	0.5	0.5
	Sub-total		0	1.0	3.0

Table 11 PROJECTED IRRIGATION WATER DEMAND BY RIVER SYSTEM (2/6)

Unit: 10^6 m^3

River Basin	Name of Tributary	No. of Scheme	1983	1990	2000
Kedah	Sg. Jelutang	(K) 70	0	0.5	0.5
Kedah	Sg. Bdg. Terap	(K) 106	0	0	1.2
"	"	(K) 107	0	0	0.6
"	"	(K) 71	0	0.7	0.7
"	"	(K) 73	0	0.6	0.6
"	"	(K) 108	0	0	2.0
"	"	(K) 105	0	0	0.3
"	"	(K) 72	0	0.8	0.8
"	"	(K) 109	0	0	1.1
"	"	(K) 110	0	0	1.5
	Sub-total		0	2.1	8.8
Kedah	Sg. Janing	(K) 111	0	0	0.3
"	"	(K) 6	2.2	2.0	2.0
	Sub-total		2.2	2.0	2.3
Kedah	Sg. Kejai	(K) 47	0	0.9	0.9
Kedah	Sg. Perik	(K) 46	0	2.5	2.5
"	"	(K) 112	0	0	0.8
	Sub-total		0	2.5	3.3
Kedah	Sg. Alor Yai	(K) 113	0	0	0.6
Kedah	Sg. Temin	(K) 78	0	0.5	0.5
"	"	(K) 79	0	0.8	0.8
"	"	(K) 129	0	0	0.4
"	"	(K) 130	0	0	0.3
"	"	(K) 131	0	0	0.5
"	"	(K) 5	1.6	1.5	1.5
"	"	(K) 132	0	0	0.6
"	"	(K) 81	0	0.5	0.5
"	"	(K) 80	0	0.3	0.3
"	"	(K) 133	0	0	2.4
"	"	(K) 21	5.4	5.0	7.6
"	"	(K) 33	18.9	18.9	25.5
	Sub-total		25.9	27.5	40.9
Kedah	Sg. Timas	(K) 114	0	0	0.7
Kedah	Sg. Pendang	(K) 115	0	0	0.3
"	"	(K) 32	1.5	1.5	1.5
"	"	(K) 120	0	0	0.4
	Sub-total		1.5	1.5	2.2
Total of I-2			29.6	38.0	63.8
Total of I			1,361.3	1,338.7	1,333.8

Table 12 PROJECTED IRRIGATION WATER DEMAND BY RIVER SYSTEM (3/6)

Unit: 10^6 m^3

River Basin	Name of Tributary	No. of Scheme	1983	1990	2000
II. Muda & Perai River System					
II-1 Main Stream					
Muda	U/S of Pinang Tungal	(K) 53	0	1.3	1.7
"	"	(K) 184	0	0	0.5
"	"	(K) 185	0	0	0.5
"	"	(K) 66	0	0.8	0.8
"	"	(K) 59	0	1.2	1.2
"	"	(K) 65	0	1.1	1.1
"	"	(K) 2	4.7	5.5	5.5
"	"	(K) 1	9.7	10.2	10.2
"	"	(K) 25	0.6	0.6	0.6
"	"	(K) 51	0	5.2	5.2
	Sub-total		15.0	25.9	27.3
Muda	Pinang Tungal System	(P.P) 2	32.8	29.8	29.8
"	"	(P.P) 4	4.7	5.2	5.2
"	"	(P.P) 3	17.3	15.7	15.7
"	"	(P.P) 6	80.5	68.7	68.7
"	"	(P.P) 1	164.6	141.6	141.6
	Sub-total		299.9	261.0	261.0
Muda	D/S of Pinang Tungal	(K) 31	5.2	5.6	5.6
"	"	(K) 4	37.5	36.4	36.4
"	"	(K) 38	0	29.1	29.1
	Sub-total		42.7	71.1	71.1
Total of II-1			357.6	358.0	359.4
II-2 Tributary					
Muda	Sg. Sok	(K) 139	0	0	0.6
"	"	(K) 140	0	0	0.5
"	"	(K) 141	0	0	0.5
"	"	(K) 82	0	0.7	0.7
"	"	(K) 83	0	0.5	0.5
	Sub-total		0	1.2	2.8
Muda	Sg. Beris	(K) 84	0	0.6	0.6
"	"	(K) 142	0	0	0.6
	Sub-total		0	0.6	1.2

Table 13 PROJECTED IRRIGATION WATER DEMAND BY RIVER SYSTEM (4/6)

Unit: 10^6 m^3

River Basin	Name of Tributary	No. of Scheme	1983	1990	2000
Muda	Sg. Kerik	(K) 143	0	0	0.5
Muda	Sg. Jemeri	(K) 144	0	0	0.6
"	"	(K) 85	0	0.6	0.6
"	"	(K) 12	4.5	4.0	4.0
	Sub-total		4.5	4.6	5.2
Muda	Sg. Begia	(K) 145	0	0	0.4
Muda	Sg. Chepil	(K) 86	0	1.1	1.1
"	"	(K) 146	0	0	1.2
"	"	(K) 149	0	0	1.6
"	"	(K) 147	0	0	1.0
"	"	(K) 148	0	0	0.8
"	"	(K) 87	0	2.3	2.3
"	"	(K) 15	2.1	1.9	1.9
"	"	(K) 150	0	0	1.0
"	"	(K) 52	0	1.5	1.5
"	"	(K) 44	0	3.6	3.6
	Sub-total		2.1	10.4	16.0
Muda	Sg. Cajad	(K) 88	0	0.5	0.5
"	"	(K) 151	0	0	0.5
	Sub-total		0	0.5	1.0
Muda	Sg. Tembak	(K) 152	0	0	0.7
"	"	(K) 153	0	0	0.4
"	"	(K) 58	0	1.6	1.6
"	"	(K) 154	0	0	0.4
"	"	(K) 63	0	2.8	2.8
	Sub-total		0	4.4	5.9
Muda	Sg. Ketil	(K) 155	0	0	0.4
"	"	(K) 156	0	0	0.6
"	"	(K) 158	0	0	0.5
"	"	(K) 159	0	0	0.4
"	"	(K) 26	1.7	2.0	2.0
"	"	(K) 91	0	0.7	0.7
"	"	(K) 160	0	0	0.6
"	"	(K) 89	0	1.0	1.0
"	"	(K) 10	0.7	0.6	0.6
"	"	(K) 164	0	0	0.4
"	"	(K) 167	0	0	0.5
"	"	(K) 165	0	0	0.4
"	"	(K) 166	0	0	0.5

Table 14 PROJECTED IRRIGATION WATER DEMAND BY RIVER SYSTEM (5/6)

Unit: 10^6 m^3

River Basin	Name of Tributary	No. of Scheme	1983	1990	2000
Muda	Sg. Ketil	(K) 169	0	0	0.5
"	"	(K) 90	0	1.0	1.0
"	"	(K) 172	0	0	0.5
"	"	(K) 168	0	0	0.3
"	"	(K) 162	0	0	2.1
"	"	(K) 173	0	0	1.0
"	"	(K) 9	1.1	0.9	0.9
"	"	(K) 174	0	0	0.3
"	"	(K) 175	0	0	0.5
"	"	(K) 40	0	2.1	2.1
"	"	(K) 26	1.7	2.0	2.0
"	"	(K) 170	0	0	1.0
"	"	(K) 8	4.3	3.9	3.9
"	"	(K) 163	0	0	0.9
"	"	(K) 157	0	0	1.2
"	"	(K) 41	0	2.0	2.3
"	"	(K) 92	0	0.6	0.6
"	"	(K) 161	0	0	1.2
"	"	(K) 171	0	0	0.6
"	"	(K) 93	0	2.4	2.4
"	"	(K) 3	5.6	5.0	5.0
"	"	(K) 60	0	1.6	1.6
"	"	(K) 34	0.9	0.8	0.8
"	"	(K) 94	0	1.3	1.3
	Sub-total		16.0	27.9	42.6
Muda	Sg. Sedim	(K) 176	0	0	1.0
"	"	(K) 178	0	0	0.7
"	"	(K) 179	0	0	1.3
"	"	(K) 27	0.3	0	0
"	"	(K) 35	0.8	1.0	1.0
"	"	(K) 11	1.5	1.3	1.3
"	"	(K) 29	1.3	1.5	1.5
"	"	(K) 182	0	0	1.0
"	"	(K) 19	0.9	0	0
"	"	(K) 183	0	0	0.8
"	"	(K) 43	0	2.7	2.7
"	"	(K) 177	0	0	0.9
"	"	(K) 18	1.6	1.5	1.5
"	"	(K) 180	0	0	0.9
"	"	(K) 62	0	1.9	1.9
"	"	(K) 42	0	2.5	2.5
"	"	(K) 181	0	0	0.6
"	"	(K) 57	0	1.6	1.6
"	"	(K) 30	1.2	1.1	1.1
"	"	(K) 61	0	1.6	1.6
	Sub-total		7.6	16.7	23.9

Table 15 PROJECTED IRRIGATION WATER DEMAND BY RIVER SYSTEM (6/6)

Unit: $10^6 m^3$

River Basin	Name of Tributary	No. of Scheme	1983	1990	2000
Perai	Sg. Jarak	(K) 189	0	0	1.0
"	"	(K) 190	0	0	0.9
"	"	(K) 191	0	0	0.6
"	"	(K) 14	0.6	0	0
"	"	(K) 20	1.6	0	0
"	"	(K) 96	0	1.3	1.3
"	"	(P.P) 5	2.3	2.0	2.0
	Sub-total		4.5	3.3	5.8
Perai	Sg. Kulim	(K) 97	0	0.5	0.5
"	"	(K) 24	2.5	2.3	2.3
"	"	(K) 192	0	0	2.0
	Sub-total		2.5	2.8	4.8
Total of II-2			37.2	72.4	110.1
Total of II			394.8	430.4	469.5
Total of I - II			1,756.1	1,769.1	1,803.3

Table 16 TOTAL DIVERSION REQUIREMENT OF MADA AND FRINGE AREA IN 1983

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.	192.2	188.5	155.3	83.3	170.3	189.4	173.4	117.7	0.	64.3	39.7	1374.2
1962	0.	167.9	251.6	178.7	78.8	178.2	92.8	93.3	37.6	98.2	26.3	49.4	1252.7
1963	0.	263.9	282.5	274.6	125.2	165.6	234.1	178.5	78.7	16.5	0.	14.0	1633.5
1964	0.	249.2	247.2	243.4	34.5	214.5	77.1	166.9	86.7	101.9	3.9	38.1	1463.5
1965	0.	263.6	273.3	185.5	120.1	102.6	144.8	167.7	31.0	43.1	18.7	17.2	1367.4
1966	0.	226.9	233.6	222.6	18.5	107.6	132.7	137.4	77.2	54.4	2.2	24.3	1237.5
1967	0.	199.8	228.1	178.9	12.3	141.3	34.5	151.4	44.8	51.5	11.5	42.8	1097.0
1968	0.	169.1	266.8	202.8	33.8	103.1	130.1	102.0	76.3	4.7	38.5	42.7	1170.0
1969	0.	241.8	263.0	250.2	55.9	69.6	144.9	222.6	92.3	42.2	0.	20.7	1403.1
1970	0.	219.6	245.0	267.6	29.1	115.5	127.3	125.9	54.9	0.	3.2	36.4	1224.5
1971	0.	262.4	190.3	257.4	63.5	36.5	157.2	161.7	84.7	33.7	4.7	36.6	1288.7
1972	0.	231.2	211.6	242.6	47.7	74.3	287.3	110.9	108.0	32.1	1.9	23.0	1370.6
1973	0.	167.9	270.2	178.0	21.0	87.5	195.0	105.6	15.7	19.2	19.6	17.0	1096.8
1974	0.	253.5	281.5	222.1	42.9	130.4	210.3	100.7	63.9	50.4	39.4	46.7	1441.8
1975	0.	238.1	236.3	205.6	46.1	123.2	221.4	99.0	125.3	80.7	31.0	18.8	1425.6
1976	0.	222.0	211.1	242.3	19.2	190.6	153.9	232.5	55.6	0.	0.	25.7	1352.9
1977	0.	231.7	253.1	271.3	103.6	108.5	193.5	142.9	59.3	25.1	37.3	50.6	1477.0
1978	0.	199.8	223.5	183.1	104.4	129.8	32.0	81.4	20.8	47.1	18.9	48.2	1089.1
1979	0.	167.9	323.4	152.2	112.9	84.3	220.5	126.6	57.4	120.2	7.0	30.7	1403.0
1980	0.	275.2	243.5	221.0	44.2	47.8	271.8	42.6	7.7	3.1	62.4	9.1	1228.6
1981	0.	219.6	237.4	164.6	93.6	163.8	184.0	242.5	108.0	109.6	6.9	48.6	1578.6
1982	0.	263.6	269.9	210.7	55.9	87.1	131.7	216.2	54.8	27.4	9.9	24.0	1351.2
1983	0.	231.7	225.5	268.7	100.2	25.1	130.1	130.8	9.2	27.9	104.1	49.7	1303.1
MEAN	0.	224.3	245.9	216.5	62.9	115.5	160.7	144.0	63.8	43.0	22.2	32.8	1331.7

Table 17 TOTAL DIVERSION REQUIREMENT OF MADA AND FRINGE AREA IN 1990

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.	181.7	261.2	128.9	140.2	181.1	181.1	137.5	56.7	1.2	52.0	43.9	1365.5
1962	0.	200.8	326.5	159.4	63.2	186.6	84.7	111.8	3.0	29.9	61.4	52.1	1299.5
1963	0.	213.4	325.7	239.6	149.4	146.6	188.9	136.6	30.0	0.	27.3	40.8	1498.4
1964	0.	220.4	322.4	203.2	83.3	184.3	80.5	136.3	29.3	28.0	2.8	36.8	1327.3
1965	0.	182.3	292.8	138.6	170.4	135.6	173.7	120.2	18.1	24.0	54.1	33.2	1362.9
1966	0.	157.3	248.6	187.8	63.6	108.9	102.8	121.8	57.0	18.5	50.4	12.2	1129.0
1967	0.	155.1	354.1	121.6	31.6	138.1	86.4	96.2	50.0	22.1	51.4	49.9	1156.4
1968	0.	213.2	339.5	168.4	74.1	118.4	85.9	162.9	39.9	3.9	63.9	42.9	1313.0
1969	0.	189.0	312.3	212.6	82.6	121.5	135.9	162.8	8.9	19.6	19.3	33.7	1298.1
1970	0.	202.6	309.8	181.9	118.2	124.7	117.8	108.7	25.0	0.	12.4	26.5	1227.6
1971	0.	181.7	249.8	296.8	65.1	102.9	131.4	142.8	37.8	29.3	43.5	38.5	1319.6
1972	0.	168.9	317.4	202.5	88.8	153.8	202.9	106.2	57.7	25.2	7.5	28.0	1358.9
1973	0.	200.8	333.7	114.3	112.5	112.4	154.6	102.4	8.4	16.8	62.5	26.0	1244.2
1974	0.	213.4	330.3	227.8	23.1	148.2	156.7	127.5	37.6	17.2	65.4	48.8	1396.2
1975	0.	191.0	277.9	189.6	28.9	132.6	192.5	64.0	39.2	22.1	52.2	24.3	1214.3
1976	0.	203.2	301.1	178.1	27.4	182.8	162.0	156.6	13.5	1.5	43.5	47.4	1317.0
1977	0.	189.0	365.4	261.3	96.9	86.8	145.5	118.0	25.8	11.4	52.6	52.7	1405.5
1978	0.	187.5	342.6	167.9	90.7	126.0	55.8	92.3	9.6	25.9	42.5	52.7	1193.3
1979	0.	200.8	345.2	112.4	142.0	96.1	141.8	143.2	11.8	32.5	34.0	50.6	1310.4
1980	0.	225.8	318.2	98.0	130.4	86.8	186.9	43.9	0.	4.3	50.9	5.6	1150.9
1981	0.	202.6	314.9	166.0	107.4	160.7	131.0	174.6	51.5	34.3	41.2	52.7	1436.8
1982	0.	182.1	291.6	125.9	126.2	125.0	59.4	159.4	8.8	6.0	29.8	40.3	1154.4
1983	0.	198.5	303.5	292.9	102.9	147.7	129.5	95.9	5.3	28.4	70.7	52.7	1428.2
MEAN	0.	194.0	312.4	181.5	93.0	135.1	134.2	122.7	27.2	17.5	43.1	38.8	1299.4

Table 18 TOTAL DIVERSION REQUIREMENT OF MADA AND FRINGE AREA IN 2000

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.	188.1	267.3	116.7	143.6	177.3	160.4	107.6	55.7	0.8	50.2	42.9	1311.0
1962	0.	208.5	324.7	160.5	79.8	175.2	77.3	95.4	2.9	28.6	57.5	50.8	1261.2
1963	0.	221.7	320.8	252.5	128.7	147.5	182.2	128.5	29.3	0.	5.3	33.5	1449.9
1964	0.	229.0	337.3	191.2	78.3	190.5	59.8	126.5	27.2	24.8	2.5	35.9	1302.9
1965	0.	189.2	300.6	133.8	174.0	119.9	137.6	120.2	16.4	23.1	49.6	27.0	1291.5
1966	0.	162.8	252.8	197.0	40.9	106.0	97.5	113.1	32.2	20.8	35.1	18.6	1076.6
1967	0.	161.6	364.4	130.9	18.8	141.0	75.2	90.0	12.8	21.4	49.6	48.7	1114.3
1968	0.	221.3	346.8	143.5	79.7	119.4	85.7	147.2	30.0	2.9	52.6	41.9	1270.9
1969	0.	196.6	295.9	217.1	73.1	119.2	128.5	158.6	8.3	18.8	9.9	32.9	1258.8
1970	0.	210.6	323.3	180.3	101.0	103.4	95.9	86.8	24.1	0.	10.8	25.8	1162.1
1971	0.	188.5	258.5	295.4	53.8	106.7	120.8	118.7	44.0	28.5	41.7	36.3	1293.0
1972	0.	175.2	329.1	182.9	91.4	146.4	196.7	85.8	56.3	20.7	5.7	27.0	1317.1
1973	0.	208.5	343.5	103.1	83.3	114.2	148.0	68.4	7.5	12.4	58.3	25.4	1172.5
1974	0.	221.7	340.3	233.9	32.1	151.5	149.8	87.0	35.7	15.3	62.9	47.6	1377.8
1975	0.	197.1	285.0	171.5	25.9	128.0	182.6	48.8	37.6	19.9	42.3	20.5	1159.3
1976	0.	211.3	310.3	187.0	26.3	186.9	153.4	141.6	11.5	0.	28.6	43.2	1300.1
1977	0.	196.1	376.3	276.6	75.6	96.6	141.9	107.0	17.9	11.0	50.3	51.4	1400.7
1978	0.	194.8	353.1	151.0	78.7	116.3	51.8	87.2	9.4	24.9	41.4	51.4	1160.0
1979	0.	208.5	355.3	111.1	132.9	96.7	137.5	117.1	11.5	31.0	29.6	43.8	1274.9
1980	0.	232.5	310.6	91.6	129.6	89.1	173.2	32.3	0.	4.2	49.7	5.5	1118.3
1981	0.	210.6	326.6	170.3	108.8	166.1	122.3	158.7	70.5	29.9	34.9	51.4	1450.0
1982	0.	189.1	297.0	122.9	119.5	118.6	48.9	155.4	22.5	4.1	27.6	37.5	1143.0
1983	0.	206.1	310.0	302.3	101.6	149.0	102.1	94.6	5.3	22.5	68.9	51.4	1413.7
MEAN	0.	201.3	318.7	179.3	86.0	133.1	123.0	107.7	24.7	15.9	37.6	37.0	1264.3

Table 19 RIVER MAINTENANCE FLOW

Unit: m^3/s

River System	With sewerage development 1990	With sewerage development 2000	Without sewerage development 1990	Without sewerage development 2000
Kedah	2.7	5.9	5.3	17.0
Muda	0	0	0	0
Perai (Kulim)	0.3	1.1	0.5	5.3

Table 20 ANNUAL DEFICIT BY TRIBUTARY

Basin	Tributary	1983			1990			2000		
		Average Deficit (10^6 m^3)	Maximum Deficit (10^6 m^3)	No. of Deficit Year	Average Deficit (10^6 m^3)	Maximum Deficit (10^6 m^3)	No. of Deficit Year	Average Deficit (10^6 m^3)	Maximum Deficit (10^6 m^3)	No. of Deficit Year
Kedah	Kesai	0	0	0	0	0	0	0.02	0.11	11
	Tok Khamis	0	0	0	0	0	0	0.02	0.12	13
	Tekai	0	0	0	0.02	0.21	10	0.11	0.80	13
	Jelutang	0	0	0	0.03	0.17	12	0.03	0.17	12
	Bdg. Terap	0	0	0	0.01	0.09	3	0.37	2.26	18
	Pdg. Langet	0	0	0	0	0	0	0	0	0
	Janing	0.08	0.63	13	0.07	0.55	10	0.09	0.69	13
	Berau	0	0	0	0	0	0	0	0	0
	Kejai	0	0	0	0.04	0.27	6	0.04	0.27	6
	Perik	0	0	0	0.55	1.42	23	0.60	1.58	23
	Alor Yai	0	0	0	0	0	0	0.03	0.22	12
	Tok Yan	0	0	0	0	0	0	0	0	0
	Rimba	0	0	0	0	0	0	0	0	0
	Temas	0	0	0	0	0	0	0.03	0.18	10
	Pendang	0.01	0.09	6	0.96	4.33	21	1.14	5.01	21
	Cial	0	0	0	0	0	0	0	0	0
	Arau	0	0	0	0	0	0	0	0	0
	Tomin	2.66	11.22	21	2.71	11.45	21	7.05	19.89	23
Muda	Sok	0	0	0	0	0.04	4	0.02	0.15	8
	Beris	0	0	0	0	0	0	0.01	0.04	6
	Kerik	0	0	0	0	0	0	0	0	0
	Pokeh	0	0	0	0	0	0	0	0	0
	Jemeri	0.40	1.44	22	0.44	1.53	22	0.54	1.78	23
	Begia	0	0	0	0	0	0	0.01	0.04	8
	Keduak	0	0	0	0	0	0	0	0	0
	Chepil	0.04	0.27	8	0.07	0.61	5	0.24	1.26	9
	Cajad	0	0	0	0.01	0.04	8	0.01	0.07	8
	Tembak	0	0	0	0.04	0.28	8	0.09	0.45	8
	Ketil	1.20	2.51	23	0.78	2.15	23	1.26	3.54	23
	Sedim	0.04	0.24	9	0.05	0.40	8	0.11	0.72	8
	Jerong	0	0	0	0	0	0	0	0	0
Perai	Kerah (93)	0.32	1.23	22	0.41	1.45	23	0.41	1.45	23
	Jarak (92)	0	0.01	1	0	0	0	0	0	0
	Kulim (91)	0	0	0	0	0	0	0	0	0

Table 21 MONTHLY DEFICIT OF KEDAH RIVER BASIN IN 1983

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.	185.4	172.2	133.2	62.4	160.5	181.7	165.3	106.1	0.	28.8	22.0	1217.6
1962	0.	163.0	244.3	168.5	54.7	165.7	62.4	75.7	26.1	37.9	13.7	44.4	1056.4
1963	0.	261.9	282.3	274.8	119.3	166.1	230.8	178.3	62.3	0.	0.	12.7	1588.5
1964	0.6	239.7	247.5	243.0	31.5	206.1	71.9	157.4	49.9	52.7	0.	25.1	1325.3
1965	0.	263.3	266.4	171.0	100.4	98.1	135.1	130.9	17.6	0.	0.	0.	1182.7
1966	0.	214.2	220.9	211.2	13.0	79.2	120.3	125.4	38.3	3.0	0.	0.	1025.7
1967	0.	189.9	218.1	169.8	9.0	108.5	13.2	104.9	5.3	0.	0.	0.	818.6
1968	0.	159.3	239.3	119.9	1.4	86.2	110.1	69.0	33.4	0.	0.	0.	818.7
1969	0.	225.9	254.4	246.2	53.0	46.7	109.2	148.0	45.1	17.7	0.	0.	1146.3
1970	0.	201.8	235.9	265.4	21.1	99.1	100.9	58.9	45.1	0.	0.	0.	1028.2
1971	0.	218.1	98.1	232.6	58.2	13.2	126.4	119.7	49.8	0.	0.	0.	916.1
1972	0.	205.2	192.0	128.0	17.8	53.8	278.4	101.5	25.1	0.	0.	0.	1001.8
1973	0.	141.7	253.8	135.2	0.	34.0	148.8	46.1	1.5	0.	0.	0.	761.2
1974	0.	220.3	265.5	214.6	0.	82.8	177.0	61.7	37.4	0.	0.	0.	1059.3
1975	0.	221.6	223.6	199.0	38.5	112.4	197.2	76.7	67.7	36.1	0.	0.	1172.9
1976	0.	195.0	202.2	228.6	0.	142.3	96.1	176.7	36.5	0.	0.	0.	1077.3
1977	0.	215.7	244.6	269.3	85.5	104.2	192.6	127.4	17.3	5.9	12.6	16.3	1291.2
1978	0.	195.9	222.7	183.2	98.2	121.5	9.3	47.2	12.1	6.2	1.8	6.2	904.3
1979	0.	164.5	323.2	149.9	85.2	61.0	186.2	97.7	5.2	60.2	0.	0.	1133.1
1980	0.	254.0	241.5	219.5	39.8	46.5	264.8	30.7	0.	0.	0.	0.	1096.9
1981	0.	198.8	227.0	139.7	36.1	123.0	171.8	236.6	89.7	82.6	1.3	25.7	1332.2
1982	0.	262.9	262.6	188.1	8.3	54.1	91.9	186.1	5.0	12.5	0.	0.9	1072.4
1983	0.	226.4	223.6	268.9	88.6	0.	107.6	44.9	2.8	0.	8.3	0.	971.2
MEAN	0.0	209.8	233.1	198.2	44.4	94.1	138.4	111.6	33.9	13.7	2.9	6.7	1086.9

Table 22 MONTHLY DEFICIT OF KEDAH RIVER BASIN IN 1990

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.	175.7	247.5	112.2	101.8	162.1	176.1	131.3	53.2	0.	21.4	35.6	1216.9
1962	0.	196.2	321.9	151.7	60.1	176.8	64.2	95.1	0.	2.6	39.3	50.2	1158.1
1963	0.	214.4	331.0	245.6	146.1	153.8	190.6	141.6	27.7	0.	2.5	23.2	1476.5
1964	6.6	215.6	328.8	208.0	65.8	178.8	78.4	128.6	9.4	4.1	0.	26.6	1250.8
1965	3.2	186.7	288.7	126.5	153.0	134.1	166.7	97.5	4.7	0.	13.6	0.	1174.7
1966	0.	145.9	238.5	182.6	55.1	79.1	92.9	111.7	44.6	0.	0.	0.	950.3
1967	0.	146.4	346.3	111.0	10.3	109.7	43.3	70.6	34.8	0.	6.9	0.	879.6
1968	0.	191.6	314.9	104.2	42.3	104.3	70.1	128.6	5.1	0.	10.9	3.5	975.4
1969	0.	171.6	306.5	211.4	80.2	94.4	98.9	129.5	0.	0.	0.	0.	1092.4
1970	0.	182.9	303.3	182.9	81.6	101.4	88.3	47.5	17.8	0.	0.	0.	1005.8
1971	0.	138.7	148.8	274.4	55.6	77.5	88.0	92.0	16.6	0.	0.	0.	891.7
1972	0.	139.0	297.9	97.4	49.7	136.0	196.8	97.2	19.2	0.	0.	0.	1033.2
1973	0.	169.5	319.7	86.8	26.3	53.4	110.0	69.4	0.	0.	9.7	0.	844.7
1974	0.	181.6	316.6	222.9	0.	99.2	125.5	87.3	23.1	0.	19.4	4.4	1080.0
1975	0.	172.9	267.5	185.6	26.4	123.8	172.1	46.0	21.9	0.	16.4	0.	1032.5
1976	0.	174.1	294.7	173.0	4.0	144.4	85.4	102.0	0.	0.	0.	0.	977.5
1977	0.	170.3	359.7	262.2	75.4	85.4	149.0	102.0	3.3	0.	28.2	22.5	1258.2
1978	0.	184.1	347.1	173.8	87.5	113.6	30.3	57.8	0.9	0.	19.0	12.4	1026.4
1979	0.	198.3	350.8	117.3	109.0	72.1	111.4	114.1	0.	0.	0.	3.3	1076.2
1980	0.	205.1	320.3	101.3	128.7	89.1	182.6	33.1	0.	0.	0.	0.	1060.1
1981	0.	179.2	307.1	143.1	49.7	122.3	121.3	170.8	41.2	14.1	19.5	32.8	1201.0
1982	0.	185.8	287.9	117.4	46.2	74.7	30.9	131.1	0.	0.	2.3	7.9	884.2
1983	0.	193.4	305.9	298.8	79.1	79.1	109.5	26.5	0.	0.	19.1	0.	1111.3
MEAN	0.4	179.1	302.2	169.1	66.7	111.5	112.3	96.1	14.1	0.9	9.9	9.7	1072.1

Table 23 MONTHLY DEFICIT OF KEDAH RIVER BASIN IN 2000

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.1	190.5	263.0	107.3	114.2	169.6	165.8	109.9	58.2	0.	24.0	40.4	1243.1
1962	0.5	212.6	331.1	163.3	61.0	177.4	64.1	85.4	1.3	3.7	41.2	60.4	1202.1
1963	7.0	233.5	338.6	270.4	133.2	166.2	195.5	145.5	33.7	0.	0.	27.1	1550.7
1964	18.5	234.3	356.0	207.9	71.0	195.7	67.0	126.7	9.2	5.2	0.	34.2	1325.8
1965	15.0	204.6	307.3	131.3	165.0	130.7	139.1	102.6	5.0	0.	12.2	0.	1213.0
1966	0.	156.5	251.6	199.0	38.0	84.3	96.7	109.6	17.7	0.	0.	0.	953.3
1967	0.	157.9	364.8	129.1	12.8	118.3	39.5	67.8	0.8	0.	7.9	0.	898.9
1968	0.	205.6	333.5	92.7	56.3	115.3	76.0	123.4	0.9	0.	7.3	4.4	1015.4
1969	0.	185.4	299.7	227.4	80.4	99.8	101.9	129.2	0.	0.	0.	0.	1123.8
1970	0.	197.1	326.2	193.6	74.5	91.0	74.2	36.5	18.3	0.	0.	0.	1011.4
1971	0.	151.3	163.4	282.1	52.5	87.5	95.4	87.2	23.4	0.	0.	0.	942.9
1972	0.	151.4	318.8	105.0	59.2	138.9	199.7	84.0	19.9	0.	0.	0.	1076.8
1973	0.	183.2	338.1	83.2	10.8	57.0	113.0	38.6	0.	0.	11.0	0.7	835.7
1974	0.	196.1	335.3	238.3	0.	113.2	128.0	51.0	24.5	0.	21.0	6.8	1114.2
1975	0.	185.3	282.8	177.2	30.3	127.9	170.2	37.8	22.6	0.	11.9	0.	1046.0
1976	0.	188.0	313.4	191.6	6.3	157.3	84.9	93.4	0.9	0.	0.	0.	1035.7
1977	0.	183.5	380.4	289.9	66.8	106.8	157.9	101.1	4.6	0.	30.0	29.2	1350.3
1978	0.	200.7	370.1	168.8	83.8	112.8	29.8	58.5	2.1	0.	21.4	15.6	1063.7
1979	0.	215.4	373.2	125.7	107.3	83.4	115.1	93.6	0.	0.0	0.	1.9	1115.6
1980	0.	218.3	325.0	106.6	140.4	104.1	179.1	24.9	0.	0.	0.	0.	1098.5
1981	0.	193.3	327.6	158.0	57.6	138.3	121.9	165.2	69.2	15.7	17.9	40.9	1305.4
1982	4.3	203.7	304.6	123.8	51.1	78.5	31.9	133.8	0.	0.	4.0	9.9	945.6
1983	0.	209.0	324.9	320.0	87.9	90.1	91.6	26.3	0.	0.	20.6	0.	1170.3
MEAN	2.0	193.8	318.7	177.9	67.8	119.3	110.4	88.4	13.6	1.1	10.0	11.8	1114.7

Table 24 MONTHLY ABSTRUCTION FROM MUDA RIVER FOR PINANG TUNGAL SYSTEM IN 1983

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.	0.	6.1	5.2	3.9	6.8	4.3	1.1	4.9	0.6	4.0	3.6	40.4
1962	0.	0.	5.8	5.3	3.7	4.6	2.5	1.1	3.6	0.6	4.0	3.5	34.8
1963	0.	0.	7.1	8.3	4.1	6.6	3.7	1.1	3.6	0.6	4.0	3.4	42.6
1964	0.	0.	11.2	8.5	3.7	6.2	3.6	1.1	3.6	0.6	4.0	3.4	46.0
1965	0.	0.	10.5	8.3	3.8	10.9	6.5	1.1	3.6	0.6	4.0	3.4	52.7
1966	0.	0.	5.7	5.1	3.7	4.6	2.5	1.1	3.6	0.6	4.0	3.4	34.3
1967	0.	0.	6.1	5.3	3.7	4.8	2.5	1.1	3.6	0.6	4.0	3.4	35.2
1968	0.	0.	9.4	6.5	4.9	6.0	2.9	1.1	3.6	0.6	4.0	3.4	42.3
1969	0.	0.	7.5	6.6	4.4	4.4	2.5	1.1	3.6	0.6	4.0	3.4	38.1
1970	0.	0.	10.2	8.3	3.7	4.4	2.5	1.1	3.6	0.6	4.0	3.4	41.8
1971	0.	0.	5.7	5.9	4.6	5.8	2.6	1.1	3.6	0.6	4.0	3.4	37.4
1972	0.	0.	8.8	5.9	4.7	5.3	3.1	1.1	3.6	0.6	4.0	3.4	40.5
1973	0.	0.	6.6	5.4	3.8	4.5	2.6	1.1	3.6	0.6	4.0	3.4	35.5
1974	0.	0.	8.2	5.7	3.9	6.7	3.4	1.1	3.6	0.6	4.0	3.6	40.7
1975	0.	0.	5.7	4.9	3.8	5.4	2.7	1.1	3.6	0.6	4.0	3.4	35.3
1976	0.	0.	6.5	8.5	3.7	5.7	3.5	1.1	3.7	0.6	4.0	3.4	40.7
1977	0.	0.	11.8	12.8	5.5	8.7	5.9	1.1	3.6	0.6	4.0	3.8	57.7
1978	0.	0.	10.4	9.7	3.9	7.6	3.6	1.1	3.6	0.6	4.1	9.0	53.7
1979	0.	0.	15.3	11.3	5.0	8.0	6.2	1.1	3.6	0.6	4.0	3.7	58.8
1980	0.	0.	12.2	11.3	5.0	5.7	5.6	1.1	3.6	0.6	4.0	3.4	52.4
1981	0.	0.	9.8	4.8	3.7	4.6	4.8	1.1	3.7	0.6	4.0	7.8	44.9
1982	0.	0.	15.3	11.3	3.7	6.6	5.4	1.3	3.8	0.6	4.0	3.4	55.4
1983	0.	0.	11.2	13.9	3.8	5.0	2.8	1.1	3.6	0.6	4.3	3.7	50.1
MEAN	0.	0.	9.0	7.8	4.1	6.0	3.7	1.1	3.7	0.6	4.0	3.9	44.0

Table 25 MONTHLY ABSTRUCTION FROM MUDA RIVER FOR PINANG TUNGAL SYSTEM IN 1990

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.	0.	6.1	5.8	4.1	7.4	4.0	1.0	5.0	0.6	3.6	3.2	40.8
1962	0.	0.	6.1	4.8	3.4	4.3	2.3	1.0	3.3	0.6	3.6	3.2	32.5
1963	0.	0.	8.0	9.8	4.0	7.3	3.9	1.0	3.3	0.6	3.6	3.1	44.5
1964	0.	0.	10.4	9.3	3.4	7.2	3.6	1.0	3.3	0.6	3.6	3.5	45.8
1965	0.	0.	10.1	9.2	3.8	10.3	5.5	1.0	3.3	0.6	3.6	3.1	50.5
1966	0.	0.	6.2	4.6	3.4	5.1	2.3	1.0	3.3	0.6	3.6	3.1	33.2
1967	0.	0.	6.4	5.1	3.4	4.3	2.3	1.0	3.3	0.6	3.6	3.1	33.0
1968	0.	0.	9.6	6.6	4.4	7.5	2.8	1.0	3.5	0.6	3.6	3.1	42.6
1969	0.	0.	8.0	7.6	4.1	4.0	2.3	1.0	3.5	0.6	3.6	3.1	37.6
1970	0.	0.	9.9	7.6	3.4	4.5	2.3	1.0	3.3	0.6	3.6	3.1	39.1
1971	0.	0.	6.4	6.8	4.8	5.7	3.0	1.0	3.3	0.6	3.6	3.1	39.3
1972	0.	0.	9.2	6.3	4.3	6.6	3.7	1.0	3.3	0.6	3.6	3.1	41.6
1973	0.	0.	6.9	6.9	3.4	4.1	2.3	1.0	3.3	0.6	3.6	3.1	35.1
1974	0.	0.	8.9	5.7	3.5	8.3	4.1	1.0	3.4	0.6	3.6	4.1	43.0
1975	0.	0.	5.1	4.5	3.5	4.9	2.7	1.0	3.3	0.6	3.6	3.1	32.2
1976	0.	0.	7.4	9.1	3.5	6.6	3.3	1.0	3.7	0.6	3.6	3.1	41.9
1977	0.	0.	10.8	12.1	5.9	9.1	5.6	1.0	3.5	0.6	3.6	3.4	55.6
1978	0.	0.	10.1	9.3	3.6	8.3	3.5	1.0	3.3	0.6	4.1	8.0	51.8
1979	0.	0.	13.3	10.5	5.4	7.7	5.6	1.0	3.3	0.6	3.6	3.3	54.3
1980	0.	0.	10.9	11.2	5.3	6.3	5.3	1.0	3.3	0.6	3.6	3.1	50.6
1981	0.	0.	9.7	4.9	3.4	5.3	4.7	1.0	3.3	0.6	4.2	7.4	44.4
1982	0.	0.	13.3	10.6	3.4	6.9	4.9	1.0	3.5	0.6	3.6	3.1	50.9
1983	0.	0.	10.5	12.6	3.5	5.3	3.2	1.0	3.3	0.6	4.5	3.5	48.0
MEAN	0.	0.	8.8	7.9	3.9	6.4	3.6	1.0	3.4	0.6	3.7	3.6	43.0

Table 26 MONTHLY ABSTRUCTION FROM MUDA RIVER FOR PINANG TUNGAL SYSTEM IN 2000

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.	0.	6.2	5.9	4.2	7.7	4.1	1.0	5.2	0.6	3.6	3.2	41.7
1962	0.	0.	6.3	4.9	3.4	4.4	2.3	1.0	3.3	0.6	3.6	3.2	32.9
1963	0.	0.	8.2	10.1	4.0	7.6	4.1	1.0	3.3	0.6	3.6	3.1	45.6
1964	0.	0.	10.7	9.6	3.4	7.4	3.7	1.0	3.3	0.6	3.6	3.5	46.7
1965	0.	0.	10.3	9.5	3.9	10.6	5.7	1.0	3.3	0.6	3.6	3.1	51.6
1966	0.	0.	6.4	4.6	3.4	5.3	2.3	1.0	3.3	0.6	3.6	3.1	33.5
1967	0.	0.	6.5	5.1	3.4	4.3	2.3	1.0	3.3	0.6	3.6	3.1	33.2
1968	0.	0.	9.8	6.7	4.4	7.8	2.9	1.0	3.5	0.6	3.6	3.1	43.3
1969	0.	0.	8.2	7.8	4.1	4.0	2.3	1.0	3.5	0.6	3.6	3.1	38.2
1970	0.	0.	10.1	7.7	3.4	4.6	2.3	1.0	3.3	0.6	3.6	3.1	39.6
1971	0.	0.	6.6	7.1	4.9	6.9	3.2	1.0	3.3	0.6	3.6	3.1	40.3
1972	0.	0.	9.4	6.4	4.4	6.9	3.8	1.0	3.3	0.6	3.6	3.1	42.5
1973	0.	0.	7.1	7.1	3.4	4.1	2.4	1.0	3.3	0.6	3.6	3.1	35.6
1974	0.	0.	9.1	5.7	3.6	8.5	4.2	1.0	3.4	0.6	3.6	4.3	44.1
1975	0.	0.	5.1	4.5	3.5	5.0	2.7	1.0	3.3	0.6	3.6	3.1	32.3
1976	0.	0.	7.6	9.4	3.5	6.8	3.5	1.0	3.8	0.6	3.6	3.1	42.8
1977	0.	0.	11.0	12.4	6.0	9.4	5.8	1.0	3.6	0.6	3.6	3.4	56.8
1978	0.	0.	10.4	9.6	3.6	8.6	3.7	1.0	3.4	0.6	4.2	8.3	53.1
1979	0.	0.	13.5	10.8	5.5	7.9	5.8	1.0	3.3	0.6	3.6	3.5	55.2
1980	0.	0.	11.2	11.5	5.5	6.4	5.5	1.0	3.3	0.6	3.6	3.1	51.6
1981	0.	0.	10.0	5.0	3.4	5.4	4.8	1.0	3.3	0.6	4.2	7.7	45.4
1982	0.	0.	13.4	10.8	3.4	7.2	5.1	1.0	3.5	0.6	3.6	3.1	51.7
1983	0.	0.	10.8	12.9	3.5	5.5	3.3	1.0	3.3	0.6	4.6	3.7	48.9
MEAN	0.	0.	9.0	8.0	4.0	6.6	3.7	1.0	3.4	0.6	3.7	3.7	43.8

Table 27 MONTHLY ABSTRUCTION AT INTAKE 20 FOR PULAU PINANG WATER SUPPLY IN 1983

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	2.9	2.9	2.7	2.5	2.9	3.6	3.8	4.1	3.8	2.8	2.5	2.6	37.0
1962	2.6	2.3	2.6	2.5	2.6	2.5	2.6	2.6	2.6	2.6	2.5	2.6	30.4
1963	2.8	3.3	2.9	3.4	2.9	3.4	4.2	4.0	3.7	2.8	2.5	2.6	38.6
1964	2.6	3.6	4.4	3.3	2.6	3.5	3.3	2.7	2.5	2.6	2.5	2.6	36.0
1965	3.8	4.5	4.5	3.6	3.4	4.5	4.8	3.6	2.6	2.6	2.5	2.6	42.9
1966	2.6	2.5	2.6	2.5	2.6	2.7	2.6	3.0	2.7	2.6	2.5	2.6	31.4
1967	2.6	2.3	2.6	2.5	2.6	2.5	2.6	2.9	2.5	2.6	2.5	2.6	30.7
1968	2.8	3.8	4.3	2.6	2.6	2.8	2.6	2.6	2.7	2.7	2.5	2.6	34.4
1969	2.6	3.1	2.9	3.4	2.9	2.5	3.0	3.1	3.0	2.6	2.5	2.6	34.1
1970	2.6	2.9	4.2	3.2	2.6	2.7	2.6	2.7	2.5	2.6	2.5	2.6	33.4
1971	2.6	2.4	2.6	2.7	2.9	3.1	3.7	2.8	2.5	2.7	2.5	2.6	33.0
1972	2.8	2.5	3.8	2.6	2.7	2.9	3.9	4.0	2.9	2.7	2.5	2.6	35.6
1973	2.6	3.2	3.2	2.5	2.6	2.5	2.8	2.6	2.5	2.6	2.5	2.6	32.1
1974	2.7	2.6	3.5	2.5	2.6	3.5	3.5	3.6	3.1	2.8	2.5	3.0	35.8
1975	2.6	2.3	2.6	2.5	2.6	2.5	2.8	3.3	2.5	2.7	2.5	2.6	31.5
1976	3.0	3.6	3.1	3.3	2.8	3.4	4.3	3.9	2.9	2.6	2.5	2.6	38.0
1977	2.9	3.2	4.8	4.5	3.4	3.9	4.9	4.2	2.7	2.6	2.5	2.6	42.1
1978	3.1	4.2	4.5	3.6	2.6	3.6	4.5	3.8	2.7	2.7	2.7	4.6	42.6
1979	5.6	5.9	7.5	4.3	3.6	3.7	4.7	4.0	2.5	2.6	2.5	2.6	49.4
1980	3.7	4.4	4.9	4.1	3.8	3.1	4.7	2.6	2.5	2.6	2.5	2.6	41.5
1981	2.7	3.5	3.7	2.5	2.6	2.8	4.3	3.5	2.5	2.7	2.5	4.3	37.7
1982	5.5	5.8	7.4	4.8	2.6	3.5	5.1	5.9	3.6	2.6	2.5	2.6	51.8
1983	2.7	3.8	4.4	4.8	2.6	2.6	3.5	4.9	2.5	2.6	3.0	3.2	40.5
MEAN	3.0	3.4	3.9	3.2	2.8	3.1	3.7	3.5	2.8	2.6	2.5	2.8	37.4

Table 28 MONTHLY ABSTRUCTION AT INTAKE 20 FOR PULAU PINANG WATER SUPPLY IN 1990

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	3.7	5.3	3.2	1.3	3.2	9.0	8.3	10.3	9.7	2.4	0.	0.	56.5
1962	0.	1.3	2.0	0.	0.0	1.8	2.1	3.1	4.7	0.3	0.	0.7	16.1
1963	3.9	7.9	6.0	8.4	4.8	8.6	10.7	10.0	9.4	1.8	0.	0.	71.7
1964	4.2	8.9	11.4	7.1	2.4	8.8	5.7	4.5	0.	0.	0.5	4.6	58.0
1965	9.3	11.7	11.7	9.0	7.4	11.7	10.2	6.7	3.8	0.8	0.	0.	82.1
1966	1.0	4.2	3.1	0.2	1.7	4.3	3.7	6.0	4.2	0.0	0.	0.	28.5
1967	0.	0.1	3.2	0.2	0.	0.3	1.1	5.0	3.6	0.	0.	0.1	13.5
1968	5.2	9.7	10.8	1.4	0.8	6.7	4.4	2.9	6.0	3.4	0.3	0.9	52.5
1969	3.2	7.6	6.5	7.5	2.5	1.2	6.7	5.2	6.6	0.8	0.	0.4	48.2
1970	0.8	6.7	10.9	3.9	1.0	5.5	1.6	4.6	1.0	0.	0.	0.	36.0
1971	2.0	3.1	3.2	3.8	6.4	7.5	9.2	4.7	1.8	2.1	2.7	0.	46.6
1972	4.2	4.4	9.4	1.8	4.4	6.4	9.7	10.1	4.5	1.6	0.	0.	56.6
1973	4.0	7.7	6.6	3.2	2.0	1.0	4.3	2.5	5.0	1.3	0.	0.1	37.8
1974	4.9	4.4	8.6	1.4	2.1	8.6	8.6	8.6	4.7	4.3	1.6	7.2	64.9
1975	2.1	1.2	0.2	0.	1.1	2.5	4.2	7.9	3.0	5.1	0.	0.6	27.9
1976	5.3	8.8	7.0	7.2	4.9	8.3	11.1	9.2	4.1	0.	0.	1.2	66.9
1977	4.6	7.7	12.4	11.6	7.9	9.8	12.8	10.4	3.2	0.	0.	0.	80.5
1978	6.9	10.7	11.6	7.7	1.1	8.8	11.5	9.1	5.1	2.6	4.4	12.3	91.7
1979	14.4	13.9	16.4	9.1	8.5	8.8	11.9	8.4	0.	1.7	0.5	1.1	94.7
1980	8.9	11.4	13.2	10.6	9.8	5.7	12.1	0.4	0.	0.	0.	0.	72.2
1981	3.1	8.2	8.4	2.2	0.9	5.1	10.3	6.5	0.	3.6	3.1	11.3	62.8
1982	14.2	13.8	16.3	10.3	0.6	8.3	13.3	14.8	8.3	0.	0.	0.	100.0
1983	2.8	9.5	11.4	12.3	0.8	3.5	8.5	12.7	0.4	2.8	6.9	6.5	78.1
MEAN	4.7	7.3	8.4	5.2	3.2	6.2	7.9	7.1	3.9	1.5	0.9	2.0	58.4

Table 29 MONTHLY ABSTRUCTION AT INTAKE 20 FOR PULAU PINANG WATER SUPPLY IN 2000

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	17.7	18.4	17.6	14.0	16.3	23.8	23.0	25.3	24.4	14.5	10.2	11.7	217.0
1962	10.4	14.5	17.6	11.7	11.5	15.6	15.9	18.3	19.6	11.5	10.9	14.4	172.0
1963	17.5	21.5	20.6	23.2	19.4	23.4	25.9	25.1	24.1	13.0	10.1	10.8	234.6
1964	18.7	23.0	26.6	21.5	16.2	23.6	20.1	18.9	10.1	10.4	11.7	20.0	220.7
1965	24.4	25.1	26.9	23.8	22.7	26.5	24.7	20.9	17.7	12.0	10.1	10.5	245.2
1966	15.1	18.0	18.6	12.5	17.0	18.1	19.0	21.2	18.9	11.6	11.8	11.0	192.9
1967	11.0	12.5	18.6	11.8	10.5	14.0	16.2	19.9	18.5	12.1	10.1	13.6	168.9
1968	20.4	23.7	26.1	13.7	14.0	21.6	19.8	18.0	20.6	17.8	12.0	15.9	223.8
1969	17.9	21.2	21.7	22.3	15.3	15.1	22.0	18.8	21.4	12.1	10.2	12.3	210.4
1970	13.2	20.4	26.1	16.1	14.4	20.4	15.2	19.8	14.1	11.0	10.1	10.4	191.2
1971	16.2	15.5	17.9	18.7	21.8	22.3	24.5	19.1	15.1	14.9	16.8	10.5	213.2
1972	18.7	18.5	24.6	14.6	19.5	21.3	24.9	25.1	17.9	14.3	10.1	11.0	220.5
1973	19.3	21.3	21.6	16.5	15.7	14.5	19.3	17.0	19.8	14.1	11.2	11.9	202.0
1974	20.1	17.3	23.8	15.5	15.9	23.3	23.8	23.6	18.6	17.8	15.8	22.6	238.3
1975	16.1	14.3	11.7	10.3	16.3	17.5	19.6	23.1	17.4	20.4	11.2	13.2	191.1
1976	20.3	22.8	22.4	21.5	19.4	23.2	26.3	24.3	16.8	10.6	10.1	15.6	233.2
1977	18.2	21.2	27.6	26.4	23.2	24.7	27.9	25.5	16.5	10.4	10.5	11.0	243.2
1978	22.0	24.2	26.8	21.7	14.3	23.7	26.6	24.2	20.0	15.4	19.2	27.6	265.7
1979	29.4	27.5	31.7	23.1	23.8	23.6	27.1	22.5	10.8	15.4	11.4	14.3	260.6
1980	24.1	25.4	28.3	25.3	25.0	19.6	27.3	12.4	10.8	10.7	10.7	10.4	230.0
1981	17.7	21.4	23.3	15.4	13.6	19.2	25.5	20.5	10.8	17.9	17.2	26.6	229.1
1982	29.2	27.4	31.6	24.7	13.4	23.1	28.4	29.7	22.2	11.9	10.1	10.9	262.8
1983	16.6	23.1	26.7	27.1	13.6	16.8	23.8	27.7	12.1	17.8	21.6	21.2	248.0
MEAN	18.9	20.8	23.4	18.8	17.1	20.7	22.9	21.8	17.3	13.8	12.3	14.7	222.6

Table 30 MONTHLY DEFICIT OF MUDA RIVER BASIN IN 1983

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1962	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1963	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1964	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1965	0.	0.	0.1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.1
1966	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1967	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1968	0.	0.	6.0	4.2	0.1	5.9	0.	0.	0.	0.	0.	0.	16.2
1969	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1970	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1971	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1972	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1973	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1974	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1975	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1976	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1977	0.	0.	12.5	14.8	0.1	0.	0.	0.	0.	0.	0.	0.	27.4
1978	0.	0.5	5.3	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.8
1979	0.0	3.0	26.6	4.8	0.	0.	0.	0.	0.	0.	0.	0.	34.4
1980	0.	0.	6.0	2.7	0.	0.	0.	0.	0.	0.	0.	0.	8.8
1981	0.	0.	8.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	8.0
1982	0.	5.9	25.9	4.3	0.	0.	0.	0.	0.	0.	0.	0.	36.1
1983	0.	0.	11.1	20.5	0.	0.	0.	0.	0.	0.	0.	0.	31.6
MEAN	0.0	0.4	4.4	2.2	0.0	0.3	0.	0.	0.	0.	0.	0.	7.3

Table 31 MONTHLY DEFICIT OF MUDA RIVER BASIN IN 1990

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1962	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1963	0.	0.	3.7	2.0	0.	0.	0.	0.	0.	0.	0.	0.	5.6
1964	0.	0.	9.1	1.4	0.	0.	0.	0.	0.	0.	0.	0.	10.5
1965	0.	0.	7.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	7.5
1966	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1967	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1968	0.	0.	22.6	17.2	3.2	21.0	0.	0.	0.	0.	0.	0.	63.9
1969	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1970	0.	0.	0.9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.9
1971	0.	0.	0.	0.	0.	0.7	0.	0.	0.	0.	0.	0.	0.7
1972	0.	0.	4.8	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.8
1973	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1974	0.	0.	4.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.0
1975	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1976	0.	0.	0.	5.1	0.	0.	0.	0.	0.	0.	0.	0.	5.1
1977	0.	0.	28.8	32.4	4.8	2.6	5.1	0.	0.	0.	0.	0.	73.6
1978	0.	0.	20.1	3.9	0.	0.	0.	0.	0.	0.	0.	0.	24.0
1979	0.	0.1	42.0	11.4	0.	0.	3.7	0.	0.	0.	0.	0.	57.2
1980	0.	0.	20.1	9.7	0.	0.	0.6	0.	0.	0.	0.	0.	30.4
1981	0.	0.	23.3	0.	0.	0.	0.	0.	0.	0.	0.	0.	23.3
1982	0.	1.1	41.8	8.3	0.	0.	0.	0.	0.	0.	0.	0.	51.2
1983	0.	0.	26.9	39.8	0.	0.	0.	0.	0.	0.	0.	0.	66.7
MEAN	0.	0.1	11.1	5.7	0.3	1.1	0.4	0.	0.	0.	0.	0.	18.7

Table 32 MONTHLY DEFICIT OF MUDA RIVER BASIN IN 2000

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.	0.	0.8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.8
1962	0.	0.	1.3	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.3
1963	0.	0.	19.0	20.6	0.	0.	0.	0.	0.	0.	0.	0.	39.7
1964	0.	0.	24.7	10.5	0.	0.	0.	0.	0.	0.	0.	0.	35.2
1965	0.	0.	24.0	0.	0.	2.3	1.4	0.	0.	0.	0.	0.	27.8
1966	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1967	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1968	0.	0.	38.7	35.4	20.1	42.0	0.7	0.	0.	0.	0.	0.	136.9
1969	0.	0.	2.6	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.6
1970	0.	0.	5.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.0
1971	0.	0.	0.	2.6	1.1	10.0	0.	0.	0.	0.	0.	0.	13.8
1972	0.	0.	16.1	1.2	2.8	5.1	0.	0.	0.	0.	0.	0.	25.2
1973	0.	0.	4.6	3.5	0.	0.	0.	0.	0.	0.	0.	0.	8.0
1974	0.	0.	14.5	3.1	0.	1.2	4.3	0.	0.	0.	0.	0.	23.1
1975	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1976	0.	0.	0.4	17.0	0.	0.	0.	0.	0.	0.	0.	0.	17.4
1977	0.	0.	44.4	54.0	16.2	9.6	20.8	0.	0.	0.	0.	0.	145.0
1978	0.	8.7	39.5	11.1	0.	0.	0.	0.	0.	0.	0.	1.6	61.0
1979	6.3	14.3	62.2	20.5	3.3	5.6	11.0	0.	0.	0.	0.	0.9	124.1
1980	0.	2.6	36.5	19.4	0.	0.	6.8	0.	0.	0.	0.	0.	65.3
1981	0.	0.	38.8	0.	0.	0.	0.	0.	0.	0.	0.	8.3	47.1
1982	6.1	17.4	62.6	16.6	0.	0.	0.	0.	0.	0.	0.	0.	102.7
1983	0.	0.2	47.0	60.4	0.	3.7	0.8	0.	0.	0.	0.	0.	112.2
MEAN	0.5	1.9	21.0	12.0	1.9	3.5	2.0	0.	0.	0.	0.	0.5	43.2

Table 33 MONTHLY OUTFLOW OF MENGKUANG DAM FOR SUPPLY TO PULAU PINANG IN 1983

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1962	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1963	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1964	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1965	0.	0.	0.1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.1
1966	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1967	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1968	0.	0.	1.8	1.3	0.1	1.5	0.	0.	0.	0.	0.	0.	4.7
1969	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1970	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1971	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1972	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1973	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1974	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1975	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1976	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1977	0.	0.	2.4	2.9	0.1	0.	0.	0.	0.	0.	0.	0.	5.5
1978	0.	0.3	1.7	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.0
1979	0.0	2.0	5.5	0.9	0.	0.	0.	0.	0.	0.	0.	0.	8.5
1980	0.	0.	1.8	0.6	0.	0.	0.	0.	0.	0.	0.	0.	2.5
1981	0.	0.	1.4	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.4
1982	0.	2.3	5.5	1.0	0.	0.	0.	0.	0.	0.	0.	0.	8.8
1983	0.	0.	2.3	3.4	0.	0.	0.	0.	0.	0.	0.	0.	5.7
MEAN	0.0	0.2	1.0	0.4	0.0	0.1	0.	0.	0.	0.	0.	0.	1.7

Table 34 MONTHLY OUTFLOW OF MENGKUANG DAM FOR SUPPLY TO PULAU PINANG IN 1990

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1962	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1963	0.	0.	1.8	2.0	0.	0.	0.	0.	0.	0.	0.	0.	3.7
1964	0.	0.	4.4	1.4	0.	0.	0.	0.	0.	0.	0.	0.	5.8
1965	0.	0.	4.4	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.4
1966	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1967	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1968	0.	0.	6.0	1.0	0.6	4.9	0.	0.	0.	0.	0.	0.	12.6
1969	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1970	0.	0.	0.9	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.9
1971	0.	0.	0.	0.	0.	0.7	0.	0.	0.	0.	0.	0.	0.7
1972	0.	0.	2.8	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.8
1973	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1974	0.	0.	2.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.5
1975	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1976	0.	0.	0.	2.7	0.	0.	0.	0.	0.	0.	0.	0.	2.7
1977	0.	0.	7.9	9.2	2.7	1.9	3.9	0.	0.	0.	0.	0.	25.7
1978	0.	0.	7.2	1.8	0.	0.	0.	0.	0.	0.	0.	0.	9.0
1979	0.	0.1	13.2	4.2	0.	0.	3.1	0.	0.	0.	0.	0.	20.6
1980	0.	0.	7.1	3.6	0.	0.	0.6	0.	0.	0.	0.	0.	11.3
1981	0.	0.	6.4	0.	0.	0.	0.	0.	0.	0.	0.	0.	6.4
1982	0.	1.1	15.0	2.5	0.	0.	0.	0.	0.	0.	0.	0.	18.6
1983	0.	0.	7.3	11.5	0.	0.	0.	0.	0.	0.	0.	0.	18.8
MEAN	0.	0.1	3.8	1.7	0.1	0.3	0.3	0.	0.	0.	0.	0.	6.4

Table 35 MONTHLY OUTFLOW OF MENGKUANG DAM FOR SUPPLY TO PULAU PINANG IN 2000

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.	0.	0.8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.8
1962	0.	0.	1.3	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.3
1963	0.	0.	10.3	13.7	0.	0.	0.	0.	0.	0.	0.	0.	24.0
1964	0.	0.	10.3	6.9	0.	0.	0.	0.	0.	0.	0.	0.	17.3
1965	0.	0.	10.3	0.	0.	2.3	1.4	0.	0.	0.	0.	0.	14.1
1966	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1967	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1968	0.	0.	10.7	11.7	1.6	0.	0.	0.	0.	0.	0.	0.	24.0
1969	0.	0.	2.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.5
1970	0.	0.	2.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.5
1971	0.	0.	0.	2.6	1.1	7.4	0.	0.	0.	0.	0.	0.	11.2
1972	0.	0.	7.9	1.2	2.8	4.4	0.	0.	0.	0.	0.	0.	16.3
1973	0.	0.	4.3	3.5	0.	0.	0.	0.	0.	0.	0.	0.	7.7
1974	0.	0.	7.3	2.5	0.	1.2	4.3	0.	0.	0.	0.	0.	15.3
1975	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1976	0.	0.	0.4	9.1	0.	0.	0.	0.	0.	0.	0.	0.	9.4
1977	0.	0.	10.7	13.3	0.8	2.5	0.8	0.	0.	0.	0.	0.	28.1
1978	0.	8.7	13.2	2.5	0.	0.	0.	0.	0.	0.	0.	1.6	26.1
1979	6.3	13.2	3.6	0.8	2.5	4.7	1.2	0.	0.	0.	0.	0.9	33.3
1980	0.	2.6	10.3	7.4	0.	0.	5.2	0.	0.	0.	0.	0.	25.5
1981	0.	0.	10.3	0.	0.	0.	0.	0.	0.	0.	0.	7.2	17.6
1982	6.1	11.1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	17.2
1983	0.	0.2	14.6	9.2	0.	2.5	0.8	0.	0.	0.	0.	0.	27.4
MEAN	0.5	1.6	5.7	3.7	0.4	1.1	0.6	0.	0.	0.	0.	0.4	14.0

Table 36 REMAINING DEFICIT OF MUDA RIVER UNDER CONDITION WITH MENGKUANG DAM IN 1983

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1962	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1963	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1964	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1965	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1966	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1967	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1968	0.	0.	4.3	2.9	0.	4.3	0.	0.	0.	0.	0.	0.	11.5
1969	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1970	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1971	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1972	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1973	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1974	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1975	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1976	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1977	0.	0.	10.0	11.9	0.	0.	0.	0.	0.	0.	0.	0.	21.9
1978	0.	0.2	3.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.7
1979	0.	1.0	21.1	3.9	0.	0.	0.	0.	0.	0.	0.	0.	25.9
1980	0.	0.	4.2	2.1	0.	0.	0.	0.	0.	0.	0.	0.	6.3
1981	0.	0.	6.7	0.	0.	0.	0.	0.	0.	0.	0.	0.	6.7
1982	0.	3.5	20.4	3.3	0.	0.	0.	0.	0.	0.	0.	0.	27.2
1983	0.	0.	8.8	17.1	0.	0.	0.	0.	0.	0.	0.	0.	26.0
MEAN	0.	0.2	3.4	1.8	0.	0.2	0.	0.	0.	0.	0.	0.	5.6

Table 37 REMAINING DEFICIT OF MUDA RIVER UNDER CONDITION WITH MENGKUANG DAM IN 1990

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1962	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1963	0.	0.	1.9	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.9
1964	0.	0.	4.8	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.8
1965	0.	0.	3.1	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.1
1966	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1967	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1968	0.	0.	16.5	16.1	2.6	16.0	0.	0.	0.	0.	0.	0.	51.3
1969	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1970	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1971	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1972	0.	0.	2.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.0
1973	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1974	0.	0.	1.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.5
1975	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1976	0.	0.	0.	2.4	0.	0.	0.	0.	0.	0.	0.	0.	2.4
1977	0.	0.	20.8	23.2	2.1	0.6	1.2	0.	0.	0.	0.	0.	47.9
1978	0.	0.	12.9	2.1	0.	0.	0.	0.	0.	0.	0.	0.	15.0
1979	0.	0.	28.8	7.2	0.	0.	0.7	0.	0.	0.	0.	0.	36.6
1980	0.	0.	13.0	6.1	0.	0.	0.	0.	0.	0.	0.	0.	19.1
1981	0.	0.	17.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	17.0
1982	0.	0.	26.8	5.8	0.	0.	0.	0.	0.	0.	0.	0.	32.6
1983	0.	0.	19.7	28.3	0.	0.	0.	0.	0.	0.	0.	0.	48.0
MEAN	0.	0.	7.3	4.0	0.2	0.7	0.1	0.	0.	0.	0.	0.	12.3

Table 38 REMAINING DEFICIT OF MUDA RIVER UNDER CONDITION WITH MENGKUANG DAM IN 2000

Unit: 10^6 m^3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1961	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1962	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1963	0.	0.	8.7	7.0	0.	0.	0.	0.	0.	0.	0.	0.	15.7
1964	0.	0.	14.3	3.6	0.	0.	0.	0.	0.	0.	0.	0.	17.9
1965	0.	0.	13.7	0.	0.	0.	0.	0.	0.	0.	0.	0.	13.7
1966	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1967	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1968	0.	0.	28.0	23.7	18.5	42.0	0.7	0.	0.	0.	0.	0.	112.9
1969	0.	0.	0.1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.1
1970	0.	0.	2.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.5
1971	0.	0.	0.	0.	0.	2.6	0.	0.	0.	0.	0.	0.	2.6
1972	0.	0.	8.1	0.	0.	0.7	0.	0.	0.	0.	0.	0.	8.9
1973	0.	0.	0.3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.3
1974	0.	0.	7.2	0.6	0.	0.	0.	0.	0.	0.	0.	0.	7.9
1975	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1976	0.	0.	0.	8.0	0.	0.	0.	0.	0.	0.	0.	0.	8.0
1977	0.	0.	33.7	40.7	15.4	7.1	20.0	0.	0.	0.	0.	0.	116.9
1978	0.	0.	26.3	8.6	0.	0.	0.	0.	0.	0.	0.	0.	34.9
1979	0.	1.0	58.6	19.7	0.8	0.8	9.8	0.	0.	0.	0.	0.	90.8
1980	0.	0.	26.1	12.1	0.	0.	1.6	0.	0.	0.	0.	0.	39.8
1981	0.	0.	28.5	0.	0.	0.	0.	0.	0.	0.	0.	1.1	29.6
1982	0.	6.3	62.6	16.6	0.	0.	0.	0.	0.	0.	0.	0.	85.5
1983	0.	0.	32.4	51.2	0.	1.2	0.	0.	0.	0.	0.	0.	84.8
MEAN	0.	0.3	15.3	8.3	1.5	2.4	1.4	0.	0.	0.	0.	0.0	29.2

Table 39 WATER DEFICIT IN MUDA MAIN STREAM FOR VARIOUS JENIANG DISCHARGES

Jeniang release (m^3/s)	Average annual deficit 1983 (10^6m^3)	1990 (10^6m^3)	2000 (10^6m^3)	Proportion of monthly maximum deficit to demand 1983 (%)	1990 (%)	2000 (%)
Without Project	5.6	12.3	29.3	40	47	72
0	8.3	16.3	38.8	48	50	75
2	5.3	12.6	31.1	36	44	69
2.5	4.7	11.8	29.3	34	42	68
4	3.3	9.6	24.4	29	39	56
6	2.0	7.0	18.5	21	32	39
8	1.0	4.9	14.1	15	26	34

Table 40 CAPACITY OF DISCHARGE VALVES

Dam	Maximum Capacity at the Low Water Level (m^3/s)	Low Water Level (El. m)
Pedu Dam	117	67.8
Muda Dam	20	82.3
Ahning Dam	5	72
Beris Dam	15	69
Tawar-Muda Dam	10	65.5

Remark; Total of two valves.

Table 41 CAPACITY CURVE OF DISCHARGE VALVES OF PEDU DAM

Reservoir Water Level (El. m)	Valve Capacity* (m^3/s)
97.6	171
95	166
90	157
85	148
80	139
75	130
70	121
67.8	117

Remark; Total of two valves.

Table 42 SHUTDOWN DISCHARGE OF DAMS FOR 2000 DEMAND

Unit: 10^6 m^3

	Ahning	Annual Shutdown For Muda river system Beris	Annual Shutdown For Muda river system Tawar-Muda	For Kedah river system Beris	For Kedah river system Tawar-Muda
1961	12.6	0	0	37.8	37.7
62	7.7	0	0	39.2	39.2
63	5.0	3.1	3.5	44.5	44.5
64	7.6	2.0	2.3	38.8	38.7
65	9.0	1.2	1.5	30.0	30.0
66	8.0	0	0	18.8	23.3
67	10.5	0	0	22.3	22.3
68	16.8	4.0	4.7	20.9	20.9
69	9.1	0.5	0.5	34.5	34.5
70	12.3	0.4	0.5	40.5	40.5
71	16.2	0.9	1.1	21.9	21.9
72	14.5	1.0	1.1	21.3	21.3
73	20.9	0.4	0.5	4.6	4.6
74	19.2	1.0	1.1	25.4	25.4
75	11.0	0	0	28.8	28.8
76	15.3	0.8	0.9	33.6	35.2
77	9.4	4.8	5.7	17.9	17.9
78	8.6	2.5	2.8	28.4	28.4
79	11.2	5.5	6.3	33.0	33.1
80	3.6	1.8	2.2	24.6	24.6
81	19.4	0.9	1.2	28.2	28.2
82	13.4	3.7	4.1	7.9	14.6
83	16.1	1.8	2.2	21.6	21.6
	12.0	1.6	1.8	27.2	27.7

Table 43 RELATION BETWEEN ACTIVE STORAGE AND ANNUAL INFLOW

			Reservoir		
			Pedu + Muda	Ahning	Beris
(A)	Active Storage	(10^6 m^3)	1,209	200	101
(B)	Average Annual Inflow	(10^6 m^3)	826	64	109
(C)	Proportion (A)/(B)		1.46	3.13	0.93

			Reservoir		
			Reman	Tawar - Muda	Khlong - Thepha
(A)	Active Storage	(10^6 m^3)	240	54	78
(B)	Average Annual Inflow	(10^6 m^3)	339	122	87
(C)	Proportion (A)/(B)		0.71	0.44	0.90

Table 44 PROPOSED OPERATION RULE

Checking Date

January 1st

Outflow of Ahning Dam: 3 m^3/s

February 1st

Outflow of Ahning Dam till December

Judge by Pedu Dam	Outflow (m^3/s)
W.L. > 90 m	3
≤ 90 m	5

Cut in percent of MADA Irrigation Demand for Off-season Crop by Combination/1

	1990				2000			
Target Year	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Ahning Dam								
W.L. ≤ 85 m	0	10	0	0	0	10	0	0
≤ 80 m	15	0	10	0	15	0	20	10
Pedu Dam								
W.L. ≤ 95 m	20	10	0	0	20	10	0	0
94	20	10	0	0	20	10	0	10
93	30	25	0	0	30	20	0	10
92	30	25	0	10	30	20	0	15
91	40	35	30		40	30	20	
89	50	40	35		50	40	30	
87	60		40		60			

April 1st

Demand Saving in percent till the end of June by Combination/1

Pedu Dam	(1)	(2)	(3)	(4)
Drawdown in March ≥ 6.5 m	30	30	20	10

Anytime

Outflow of Beris Dam

Beris Dam	Outflow (m^3/s)
W.L. > 75 m	15
≤ 75 m	5

Demand Saving

Pedu Dam

W.L. ≤ 75 m decrease by 10%

W.L. ≤ 72 m decrease by 20%

Note /1: Combination

(1) Pedu-Muda and Ahning

(2) Pedu-Muda, Ahning and Jeniang

(3) Pedu-Muda, Ahning, Jeniang and Beris

(4) Pedu-Muda, Ahning, Jeniang, Beris and Reman

Table 45 WATER DEMAND AND SUPPLY BALANCE OF INTEGRATED OPERATION SYSTEM (1/18)

Unit: 10^6 m^3

Sources Facilities: Pedu-Muda
Case 3 (Kedah Priority)

Target Year 1983

	MUDA DEMAND (A)	MADA NORTH (B)	DEMAND SOUTH (C)	KEDAH WITHD. (D)	NORTH DEFIC. (E)	JENIANG WITHD. (F)	RELEASE NAOK (G)	RELEASE REMAN (H)	MUDA RELEA. (I)	SOUTH DEFIC. (J)	TOTAL DEFIC. (K)	RESERVOIR PEDU (L)	AHNING (M)	BERIS (N)	T.MUDA (O)	REMAIN. DEFICIT (P)	CUT RATE (Q)	TOTAL OUTPUT (R)
1961	63.1	564.9	481.3	172.3	418.0	0.	0.	0.	63.1	455.9	971.0	966.7	0.	0.	0.	3.8	0.45	1105.
1962	63.1	387.3	251.2	207.7	226.8	0.	0.	0.	63.1	204.0	478.7	478.7	0.	0.	0.	0.	0.75	702.
1963	64.0	565.3	484.2	71.7	516.0	0.	0.	0.	64.0	461.8	1086.4	895.8	0.	0.	0.	171.6	0.55	942.
1964	63.8	496.8	351.5	152.6	357.5	0.	0.	0.	63.8	338.1	772.9	772.9	0.	0.	0.	0.0	0.65	912.
1965	63.5	408.3	277.5	208.1	259.0	0.	0.	0.	63.5	218.7	530.9	530.9	0.	0.	0.	0.0	0.75	749.
1966	63.1	487.0	413.9	231.2	348.1	0.	0.	0.	63.1	321.6	744.1	744.1	0.	0.	0.	0.0	0.45	964.
1967	63.1	577.2	433.0	304.1	359.8	0.	0.	0.	63.1	346.4	784.6	784.6	0.	0.	0.	0.0	0.15	1073.
1968	67.0	547.8	378.3	350.3	281.1	0.	0.	0.	62.0	294.7	639.7	639.7	0.	0.	0.	5.0	0.35	988.
1969	63.1	633.7	488.8	278.0	405.4	0.	0.	0.	63.1	439.1	938.3	937.0	0.	0.	0.	1.2	0.35	1184.
1970	63.3	699.8	445.9	219.2	328.0	0.	0.	0.	63.3	397.0	806.3	806.3	0.	0.	0.	0.	0.55	1008.
1971	63.1	628.4	566.3	386.7	337.7	0.	0.	0.	63.1	470.3	897.8	897.8	0.	0.	0.	0.	0.15	1258.
1972	63.7	708.6	568.3	384.5	456.6	0.	0.	0.	63.7	435.8	991.6	989.6	0.	0.	0.	1.8	0.15	1339.
1973	63.1	485.3	312.7	322.9	217.4	0.	0.	0.	63.1	257.7	527.9	527.9	0.	0.	0.	0.	0.45	861.
1974	63.5	694.7	634.9	398.3	361.8	0.	0.	0.	63.5	569.4	1034.7	1034.7	0.	0.	0.	0.	0.15	1393.
1975	63.1	470.0	516.0	277.3	293.5	0.	0.	0.	63.1	415.3	787.5	785.7	0.	0.	0.	1.7	0.55	1047.
1976	63.7	480.7	412.7	270.3	254.2	0.	0.	0.	63.7	368.8	692.2	692.2	0.	0.	0.	0.0	0.55	957.
1977	66.1	690.4	668.9	210.8	571.7	0.	0.	0.	61.9	576.7	1276.1	1196.8	0.	0.	0.	75.5	0.15	1350.
1978	64.1	351.2	136.7	207.9	168.4	0.	0.	0.	62.6	109.6	308.9	308.9	0.	0.	0.	1.5	0.75	548.
1979	64.6	495.4	472.8	292.3	267.6	0.	0.	0.	59.6	408.2	750.9	750.4	0.	0.	0.	5.5	0.55	1027.
1980	64.4	402.0	313.5	146.9	288.8	0.	0.	0.	63.7	279.8	631.8	621.9	0.	0.	0.	9.6	0.65	770.
1981	64.0	750.6	547.7	265.2	521.6	0.	0.	0.	62.9	513.4	1150.1	1140.2	0.	0.	0.	10.0	0.35	1352.
1982	64.2	361.5	351.7	249.5	180.9	0.	0.	0.	58.6	282.8	515.2	515.2	0.	0.	0.	5.6	0.75	772.
1983	65.3	556.5	390.9	343.1	308.7	0.	0.	0.	60.8	295.5	671.4	671.4	0.	0.	0.	4.5	0.45	1008.
AVERAGE	63.9	532.3	430.2	256.6	336.0	0.	0.	0.	62.7	367.9	782.1	769.1	0.	0.	0.	12.9	0.45	1014.