KINGDOM OF THAILAND
MINISTRY OF AGRICULTURE AND COOPERATIVES
ROYAL IRRIGATION DEPARTMENT

MASTER PLAN STUDY
ON
THE WATER MANAGEMENT SYSTEM AND MONITORING PROGRAM
IN
THE CHAO PHRAYA RIVER BASIN

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JUNE 1989

JAPAN INTERNATIONAL COOPERATION AGENCY

THE KINGDOM OF THAILAND

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FINAL REPORT

ANNEX-2 WATER MANAGEMENT PLANNING

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ANNEX-2 WATER MANAGEMENT PLANNING

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CHAPTER 1 PRESENT WATER MANAGEMENT SYSTEM

1.1 Background

The water management in the Chao Phraya River Basin has been practised in the neatly pyramidal organization with the O & M Head Office in the RID Headquarters as its top followed by field offices (regional offices, project management offices) and respective terminal organizations.

The RID O & M Head Office, receiving water management data/information from the field offices via radio in oral communication, makes analysis and judgement on the data/information to give necessary instructions back to each field office on water distribution at the irrigation canals and operation of the facilities in keeping close coordination with the offices and organizations concerned.

The project engineers are assigned to each project office as fully responsible personnel to control several branch offices. In each branch, a water master is assigned to be responsible for the fields of about 100,000 rai, and several zonemen are deployed subordinately to assist the water master. And one zoneman covers in principle the areas in a range between 1,000 rai and 1,500 rai.

The water master has responsibility to give guidance of general farming works to the farmers in his own area, and to keep various records and data on water management on the respective canals. The zoneman, on the other hand, has responsibility to carry out maintenance of diversion works and other related irrigation facilities as well as to keep records and data of on-farm level water management so as to make report to the water master.

The present water management system was developed by Canadian Consultants, Messrs. Acres & Co., Ltd. on the base of the aforesaid field level system, and the system has been operated since 1982.

This system, in taking into consideration the effective employment of the ready provided staffs, has enabled to concentrate the data/information available on the zonemen level to the Water Management Center of the RID Headquarters. (See Figure 1-1)

The staffs of the said Center put the data concentrated thereto into the computer files. The input data are processed by computer with the Model Simulation Program available at present.

The results of the processing are utilized as references of decision-making by the Water Management Center. Recently, however, smooth processing has come to be hindered in congestion.

The Master Plan Study, therefore, will try to review the existing water management system to grasp its general conditions at present and to study the methodology of the system improvement.

1.2 Basic Concept of the Present System

In a specific area, when a water source would have such abundance as to excessively meet water demand, only facilities could be desirably provided to take the water in necessity in keeping the source water in natural flow rather than a complete water management system under specified operation rule would be provided.

Contrarily, however, when a water source would have insufficiency to meet water demand, a complete water management system would become necessary. As tension in the relation of demand and supply of water has grown larger under the present water management system in the Chao Phraya River basin, the function of the said system has come to be necessarily evaluated in appropriate manners. The system must be operated in the premise of rational water distribution to satisfy not only irrigation water supply but power generation, river navigation, municipal water supply, flood control, saline water intrusion prevention, etc.

The existing irrigation areas in the basin are divided into 106 irrigation blocks. The irrigation water requirements by blocks can be obtained by computer with existing model; however, the computation of the dependency upon the dam in the upstream will require to place the following several restrictive conditions on the flow of the water and to have better understanding in the process.

i) Flow Constraint (Maintenance flow)

Minimum discharges required for navigation, pump operation, salinity protection, etc. at the specific point of the river.

ii) Water Loss (Water use other than the above)

The amount of water unreturnable as municipal and industrial consumption

iii) Side Flow

The inflow into the irrigation areas in the Chao Phraya River basin, which can be utilized as irrigation water, although cannot be controlled in discharge.

The abundant side flow was recorded by the Nakhon Sawan observatory on those discharges in the downstream of the Pin River, as the total discharge of those rivers of Wan, Yon and the downstream of Nam River, and by the Kaeng Koi observatory on the discharge of the Pasak River.

iv) Minimum Discharge for Power Generation

It is in September and October when the water released from dams for irrigation becomes minimum, because there will be much side flow available for irrigation in these two months. In other respect, in January the irrigation water requirements become minimum in the year.

For those three months, however, EGAT has to release the possibly least amount of water from dams to generate the minimum power.

The favourable effects expected by employing the present system are to wastelessly utilize the released water from dams in the most thorough and effective use of rainfall runoff and side flow of the related tributaries and branches, and to discharge the water through the regulating gates more precisely in its amount to meet the requirements of the beneficiary areas.

1.3 Structure of the Present System

The structure of the present water management system can be explained as follows: 1) Data reporting, 2) Computer system, and 3) Output interpretation, the water management data cover rainfall, runoff, cultivated area, field moisture condition and so forth which are informed to the Water Operations Center (WOC).

1.3.1 Computer System

The computer plays an important part of present water management system, because it can manage many data at high speed to do complicate calculation an irrigation water requirement and movement of water in the management system.

This computer system is operated as following process. (See Figure 1-2)

i) Data processing
ii) Calculation of irrigation water requirement
iii) Calculation of return flow
iv) Execution of water use simulation model
v) Output of the simulation result

(1) Data processing

Rainfall, water level and discharge data are daily coded on computer coding sheet form, and then raw data are filed in the computer. The data for a total of 21 days are stored in the file at a time and the old data will be erased out when the new ones are stored. The data in the file will relate to a number of observation stations and the data in five digits.

Weekly crop data are coded on computer coding sheet form, and then, raw data are filed in the computer. The data in the file will relate to each irrigation block. Fixed data are many coefficient data for each irrigation block needed in the computation of irrigation demand and return flows.

(2) Irrigation demand calculations

The computation of irrigation demands and return flows in each irrigation block is done on the weekly basis. The general equations used in computing irrigation demand are as follows.

$$IW = \frac{CU - EFFR - DS}{EFFY} + \frac{LP}{LPEF} \qquad (1)$$

where,

IW = irrigation water required

CU = consumptive use of the crop

EFFR = effective rainfall

DS = ponding depth in paddy field (a positive DS indicated water available in storage)

EFFY = Growing period irrigation efficiency

LP = land preparation water requirements

LPEF = land preparation irrigation efficiency

CU = WCRCF x PETP

where,

WCRCF = weighted crop coefficient

PETP = potential evapotranspiration

(3) Return flow calculations

Return flow is the unconsumed water which reappears in the drainage system of an irrigation block and is available for reuse farther downstream. The theoretically available return flow is computed from a water balance in the irrigation block as follows.

$$TRF = TRC + IW - CU + DS + TRU = ETU - LP \qquad (3)$$

where,

TRF = theoretical return flow

TRC = total rain on the cropped area

IW = irrigation water delivery

CU = consumptive use

DS = ponding depth in paddy field

TRU = total rain on uncropped area

ETU = evapotranspiration from uncropped area

LP = land preparation water requirement

The actual return flow, which is the amount to reappear in the drainage system for reuse, is somewhat less than the theoretical value. The equation used in computing actual return flow is

$$RF = RFT \times TRF \qquad (4)$$

where,

RF = actual return flow

RFT = return flow factor (RFT   1.0)

(4) Execution of water use simulation model (Refer to Figure 1-3)

The water use simulation model is a weekly simulation of the major water use components of the Meklong and Chao Phraya River basins. The major structures of the irrigation system are defined as the main lateral and main drain level. The solution procedure of the simulation model solves the water requirements in this schematic in three sections which have been assigned different basin numbers.

Basin 1 - The Meklong River below Kanchanaburi
Basin 2 - The Chao Phraya River below Nakhon Sawan
Basin 3 - The Meklong and Chao Phraya Above Kanchanaburi and Nakhon Sawan respectively.

These sections are usually solved as a group in sequence, but can be solved independently if the appropriate input data are provided.

The first two sections constitute the central plain region of Thailand and contain complex irrigation and drainage systems.

The water requirement solution to these areas uses a flow network optimization technique based on the out-of kilter algorithm.

The third area listed above is the area between the major reservoirs and the central plain and the main purpose of a solution in this area is to determine reservoir operating requirements.

1.3.2 The Method of the Simulation

(1) Out-of kilter algorithm

The backbone of the simulation model is the solution of water requirements in the central plain area using a network flow optimization technique known as the out-of kilter algorithm. This technique was selected since it is extremely flexible in allowing the programmer to make structural and operational changes to the model as part of the basic input data.

Eight different components have been defined to represent the specific characteristics. (Refer to Figure 1-4)

These components are listed below.

- Irrigation Block
- Check Storages
- Regulators
- Flow Constructions (e.g. navigation, water quality)
- Drain Points
- Supply Points (e.g. pumps)
- Water Losses (e.g. Bangkok water supply)
- Side Flow (e.g. tributary inflow)

Simulation of the system is achieved by modeling each of the above component types and their characteristics with channels and nodes.

A channel connects two nodes and is composed of one or more "arcs", each of which has specific flow properties. An arc is a directed line segment which can transfer flow from one node to another. A node is used to represent a spatial junction of channels. (Refer to Figure 1-5)

(2) The flow of the simulation

The flow of the simulation is explained in Figure 1-6. The solution procedure in the program is described as follows.

DEFIN: Main routine 'DEFIN' reads all the general description data of the water use components (irrigation block, channel, return flows, check storages, regulators, flow constraints, side flow, water losses, drain points, supply points)

DMAND: Main routine 'DEMAND' compute irrigation water requirements and return flows which are eliminated ava''able rainfall plus ponding depth in paddy field from consumptive use of the crops.

GNGRD: Main routine 'GNGRD" generates a flow network grid either from cards or from data on existing disk files.

BOUND: Main routine 'BOUND' generates the upper and lower flow bounds to be imposed upon the flow network grid generated by GNGRD.

PREP: Main routine 'PREP' prepares the problem definition for the out-of kilter algorithm (OKA) by initializing the OKA solution variables.

SOLVE: Main routine 'SOLVE' initializes the working storage for use by KILTE routines (which are the basis of the out-of-kilter algorithm) and then links to main routine KILTE.

KILTE: Main routine 'KILTE' is a network flow optimization package known as the out-of kilter algorithm. It is used to solve the network flow problem defined by main routines DEFIN, GNGRD, BOUND.

OUTPT: Main routine 'OUTPT' is used to control the program direction after KILTE has solved or tried to solve the problem definition.

REDIS: Main routine 'REDIS' checks the network solution for the following conditions in order.

SUMRY: Main routine 'SUMRY' produces six summary reports of the solution of the network flow problem.

INTERP: Main routine 'INTERP' calls subroutine WINIT to read monitoring arc flow, fore cast arc flow, initial arc bounds, control parameter, run indicator and title card.

WBLAN: Main routine 'WBLAN' produces seven water balances of the solution of the network flow problems.

SIMUL: Main routine 'SIMUL' initializes the variables that are used in the program and then calls subroutines INPUT, DCRE and DMRE to determine the water demand.

REPOT: Main routine 'REPOT' initializes variables for output routines. It calls subroutine OUTP1 and OUTP2 for summary output.

1.4 Procedure of the System Operation

The simulation of present water management model is executed to verification for last week and forecast for next week and week after next (which three week calculation is one unit).

1.4.1 Calculation Week

All rainfall and stream-flow data will be up-to-date to the Tuesday of this week and all crop data for the week prior (monitoring week) will be reported to the WOC by Monday afternoon of the calculation week. Three computer runs of the WMS' are done on Wednesday and Thursday one each for the three weeks.

1.4.2 Monitoring Week

This is the week prior to the Calculation Week. The results of the WMS for this week serve to monitor the water use in the irrigation system. For this week, only observed data on crop areas, rainfall and side-flow are used in the calculation.

1.4.3 Forecast Week

This is the week immediately following the calculation week. The WMS is run to determine water allocations to the main regulator in the irrigation network. The calculation is based on forecasted cropped areas which have been projected from crops data received for the monitoring week along with historic planting calendars in each irrigation project. Long-term average rainfall is used in the calculation, and uncontrolled side-flow is forecasted based on a correlation with known side-flow and rainfall.

1.4.4 Forecast + 1 Week

This is the second week following the calculation week, i.e. it immediately follows the forecast week. Since there is a 5-day lag in the river system from the time, the water is released from the Bhumibol and Sirikit reservoirs to the time when the water arrives at the Central Plain. And it is necessary to base the reservoir release requests or irrigation demands in the Forecast + 1 Week.

1.5 Development of Supporting Sub-Programs

For improvement of the present model, supporting sub-programs have been developed under the following concepts. (See Program Manuals; Supporting Sub-Programs of the Present Simulation Model.)

- Rearrangement of procedures for parameter modification such as irrigation efficiency and system parameters for water transfer from Meklong basin.
- Study on weekly demand calculation method to the both dams.
- Hydraulic analysis of Chainat-Pasak Canal

1.5.1 Modification of Parameter

(1) Study on the modification of the parameters

Modification of only irrigation efficiencies could not improve calculation results so much because of the model characteristic. Then the return flow factor should also be modified too. The results are as follows.

1) Calculation cases

Used data are the same as those used in the last verification study, (dry season's data in 1986), and following cases were calculated.

Case	Remarks
CASE-0	Return Flow Factor = 0.75 (same value to the present model Irrigation Efficiencies = Observed value/Monitoring Ca. value * present value
CASE-1	° Phitsanulok Project .... RTFA = 0.65 EFFY = 0.10 ° Chainat-Pasak, Chainat-Ayutthaya, Raphiphatana Canal Area .... ETFA = 0.30 EFFY = 0.10
CASE-2	The case-1 value of EFFY is smaller than the present value, so EFFY = 0.5*(case-1 (0.1 + present value (0.50 - 0.55)) ° Phitsanulok Project .... RTFA = 0.65 EFFY = 0.10 ° Chainat - Pasak, Chainat-Ayutthaya, Raphiphatana Canal Area .... RTFA = 0.30 EFFY = 0.30

Note: RTFA: Return Flow Factor
EFFY: Irrigation Efficiencies

2) Results of modification study

i) Intake water volume in Chainat-Pasak Canal Area

Concerning the intake water volume, to modify EFFY is not so meaningful. One of the reasons is that water for other purposes than irrigation is led to the area. So values of EFFY, which was available for the Raphiphatana Canal area, was applied (Case-1).

ii) Intake water volume in Raphiphatana Canal Area

The valuc of EFFY in Case-1 calculation showed good fitness of the calculated regulator flow to observed one.

iii) Demand water volume for Phitsanulok Project

In this area value of Case-0 was applied.

vi) Intake water volume within Chainat-Ayutthaya Area

Observed values are greater than calculated ones. These results are more remarkable than the results of Chainat-Pasak Canal Area. For value of the parameters of EFFY and RTFA, Case-1's value may be applied.

v) Modified regulator flow at each regulator

The results show the considerable improvement. Results of reservoir release and regulator flow at Manorom and Koke Kathiem Regulators are, for instance, shown in Figure 1-7.

(2) Method of modification

The method is composed of three steps as follows.

i) The first step is to examine values of parameters EFFY and RTFA.

ii) The second step is to decide calculation cases.

iii) The third step is to calculate the cases.

Supporting computer programs prepared for carrying out the above steps are as follows.

- A program to calculate demand and return flow corresponding to modified EFFY using outputs of the present computer program "EMRFC" (say "MDFY"). Parameter RTFA is held unmodified. (for the steps i and iii)

- A program to calculate demand and return flow corresponding to both modified EFFY and RTFA using output as mentioned above (say "MDFYA"). (for the step iii)

- A program to calculate demand corresponding to modified EFFY using output as mentioned above (say "MDFYB"). Water volume of return flow is held unchanged. However, parameter RTFA is calculated corresponding to modified demand and unmodified return flow. (for the step i)

The computer program mentioned above writes the results (modified demand and return flow) to the present file No. 21. Then the simulation carries out more easily by executing the present programs (DMAND, GNGRD and SIMUL).

- A program to calculate demand, return flow and consumptive use (demand-return flow) in any area corresponding to several combination of EFFY and RTFA (say "MDFYC"). (for the step i)

1.5.2 Analysis for Weekly Demand Calculation Method to the dams (After 1984)

Demand to the dams by Weekly Model is calculated in comparison of demand calculation results in irrigated areas with power generation release. However, WOC have employed a simple method for demand calculation since 1984 as follows.

Water Demand to Dams (WDD) = Irrigation demand for Chao Phraya Delta + Irrigation demand for Phitsanulok Project + Domestic water demand + Other demands + Special demands) = Side inflow (m^3/s)

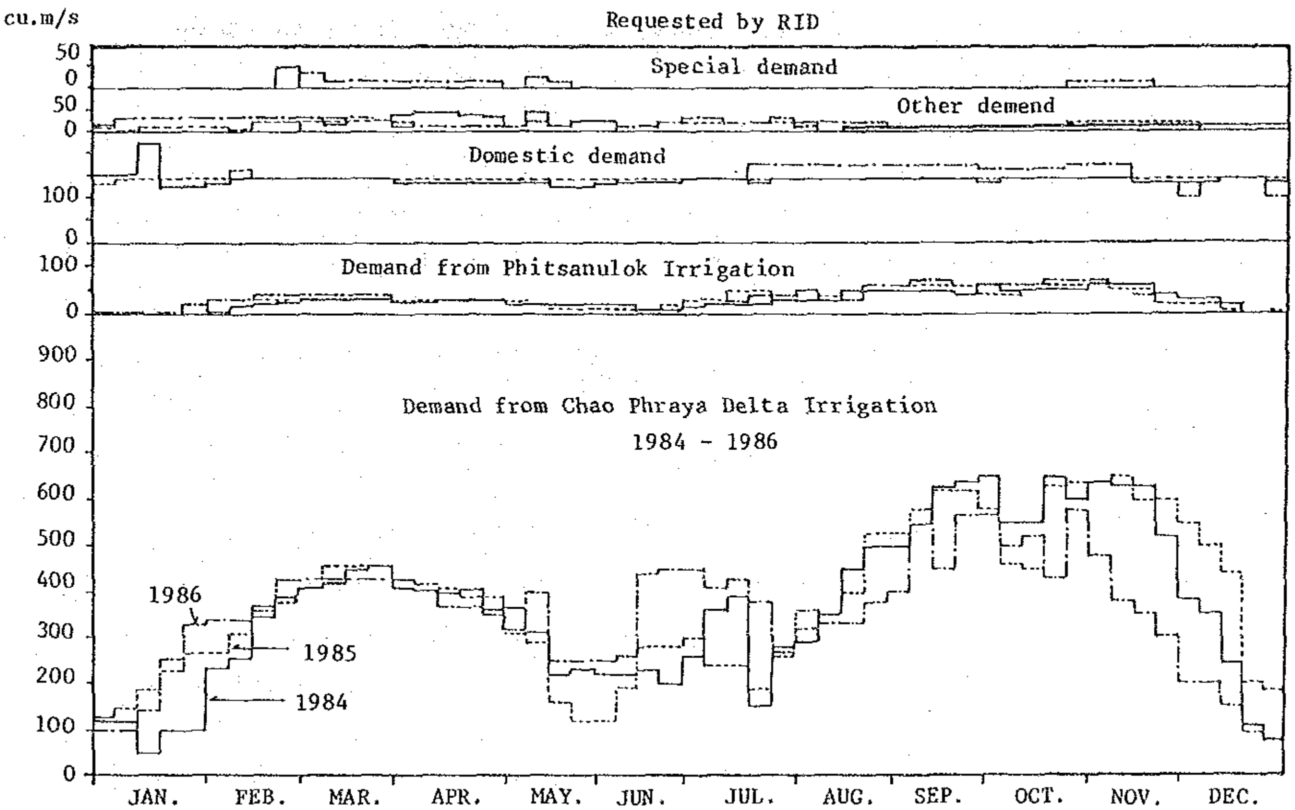
If WDD < 0
then WDD = 0 —(Equation-1)

Weekly Model have been operated in 1982, 1983 and 1986, therefore Weekly Model was operated together with (Equation-1) only in 1986. Irrigation demands calculated during dry season show approximately same pattern in three years (1984 - 1986).

Experience for Weekly Model in 1982 and 1983 were applied to estimation of irrigation demand in the delta in 1984 and 1985. RID has re-operated the Weekly Model in 1986 to examine the propriety of the model use.

It can be said that the calculation for irrigation demand in wet season in 1986 have contributed to the estimation of available rainfall, so that demand water in 1986 is smaller than that in 1984 and 1985. (Figure 1-8)

Figure 1-8. WEEKLY DEMAND TO BHUMIPOL AND SIRIKIT RESERVOIRS



1.5.3 Hydraulic Study on Chainat-Pasak Canal

In order to study hydraulic behavior of Chainat-Pasak Canal, longitudinal and cross sections, dimensions, water levels, gate opening and discharges of every three-hours at regulator were collected and analysed.

Flow capacity in the canal between each regulator is studied from water level records. A period and places of steady water flow have been selected.

(record on Jan. 14th, '87)

Regulator Name	Location (km)	Distance (km)	Upstream Water Level (m)	Downstream Water Level (m)	Discharge (cu.m/s)
Manorom	0.00	0.00	14.980	13.920	19.0
Chong Kae	46.58	46.58	13.550	11.080	19.0
Koke Kathiem	86.10	39.52	9.660	8.610	19.0
Reong Rang	120.00	33.90	8.550	6.750	19.0

Hydraulic gradient between Chong Kae Regulator and Koke Kathiem Regulator is steeper than that between Manorom Regulator and Chong Kae Regulator and between Koke Kathiem and Reong Rang Regulators.

For the analysed period, flow is comparatively small so that significant differences have been found in hydraulic gradients. The tendency has been found even when flow is abundant.

Meanwhile, lag time of water in canal from Manorom Regulator to Reong Rang Regulator is estimated by numerical unsteady flow method with assumed coefficient of roughness of canal 0.0225.

Comparison of calculated value with the observed value has been made for the period from March 6th to March 20th, during which three regulators are fully opened. The results are shown in Figures 1-9 and 1-10.

When flow in the canal is increasing and three regulators are fully opened, about two days are required as lag time from Manorom Regulator to Reong Rang Regulator. When the discharge in the canal is increasing and three regulators as partly opened, about a week is required as lag time between the same.

CHAPTER 2 EVALUATION OF WATER RESOURCES

2.1 Hydrological Characteristic

2.1.1 Rainfall Characteristic

Annual rainfall in Chao Phraya River basin fluctuates from 1,000 to 2,000 mm and its difference in upper, middle and lower basins is not significant. Wet season is from May to October. Peak rainfall occurs in August or September, and there has little rainfall from November to March. Monthly rainfall at major station in the basin are shown in Figure 2-1. Results of study on probability of annual rainfall are also shown in Table 2-1.

2.1.2 Run-off Characteristic

(1) Run-off characteristic in the basin

Run-off characteristics in sub-basin are shown in Table 2-2. Annual run-off from sub-basins shows 150 to 400 mm out of annual rainfall 1,000 to 1,200 mm, so run-off percentage shows 15 to 30%. Annual run-off at Sirikit Dam shows 440 mm, and Bhumipol shows 230 mm. Run-off percentages are 37% and 20%, respectively. Annual run-off yield at Bhumipol Dam has been decreasing, though amount of annual rainfall are almost constant. It means that water consumption in the basin is increasing because of basin development.

Annual mean flow at Nakhon Sawan amounts to 24,000 MCM, out of which release from dams is 45%. On the other hand, annual flow in Pasak River shows 2,100 MCM and annual mean yield of the basin is 140 mm. This yield is the lowest in the all Chao Phraya basin.

Study on probability of annual run-off at major station has been made as shown in Tables 2-3 and 2-4.

(2) Inflow to reservoirs

Forecasting of inflow at both reservoirs is significant for annual cropping plan. Preliminary study on forecasting is conducted as follows.

Annual average inflows of Bhumipol and Sirikit reservoirs from 1972 to 1986 are 6,000 MCM and 5,800 MCM, respectively. Most of inflow appears from April to October in wet season as shown in Table 2-5. Summary of annual inflow and basin rainfall of both reservoirs from 1972 to 1986 are as follows.

Dam	Annual Rainfall (mm)	Average Inflow (MCM)		
		Nov. - Mar.	Apr. - Oct.	Total
Bhumipol	1,170	1,380	4,620	6,000
Sirikit	1,180	740	5,070	5,810
Total	2,350	2,120	9,690	11,810

Many rainfall observation stations are located in the basin. In this study, some stations are selected provisionally and relation between basin rainfall and inflow of reservoir has been examined so as to prepare a forecarting system of inflow.

Forecasting of inflow from April to October in wet season is difficult because inflow is much dependent on amount of basin rainfall. Therefore, forecast of inflow to reservoirs has to be derived from statistic analysis of accumulated inflow data in the past. On the other hand, inflow in dry season may be easily forecasted from basin rainfall in wet season or inflow data in the past. Relation between rainfall in wet season and inflow in the next dry season from 1972 to 1986 are as follows.

Dam	Average Rainfall (mm)		Average Inflow (MCM)
	Jul. - Nov.	Sep. - Nov.	Nov. - Mar.
Bhumipol	776	429	1,380
Sirikit	756	280	740

Details are shown in Figures 2-3 and 2-4.

(3) Forecast of side flow

Water allocation to project areas through major regulators shall be planned to meet with actual reservoir release, forecast side flows and intake water requirements at major regulators derived from filed water demands. Among them, forecasting of side flow shall be made in/at the following basins and locations.

- side flows between the both dams and Nakhon Sawan
- side flow between Nakhon Sawan and Chainat
- flow of Pasak River

Forecasting side flows have been made by using rainfall and discharge data monitored in each basin and the relation previously studied on the past trend.

Study results show that sideflow is dependent on basin rainfall. During February - August, it appears as water losses along channel including consumptive use in the basin, while during September - January it appears as runoff caused by rainfall. Monthly side-flow in each basin are shown in Figures 2-5, 2-6 and 2-7. In these Figures, basin areal rainfall is calculated by average method based on the selected observation stations in each basin.

2.2 Study on Dam Operation by Water Balance Simulation Model

2.2.1 Water Balance Simulation Model

A computer simulation model for calculation of water balance in the basin has been produced so as to examine water availability for irrigation and potentiality of water resources development. In this study, past dam operation has been examined by this computer simulation model.

(1) Composition of model

For water balance study, Chao Phraya Basin is divided into fourteen sub-basins, as shown in Figure 2-8. Area of divided sub-basin are shown in Table 2-6.

Location of each sub-basin, each water requirement and its relation to storage reservoirs and river systems are considered in the simulation model. Schematic diagram of the model as shown in Figure 2-9 is used to simulate the water balance along river system.

Water balance is calculated on the basis of water requirements, inflow and outflow including return flow from each sub-basin. Water requirements are based on consumptive use by crops and rainfall in each sub-basin.

Water balance is computed in each month of the simulation period, considering monthly cropped area, planted area and their growing stages.

(2) Hydrology data

Hydrology data are used in the schematic diagram to estimate the amount of water resources in the basin.

- Rainfall

  Raingauge stations in the basins are selected as shown in Figure 2-10. In this model, basin areal rainfall is estimated by average method.

- Stream flow

  Monthly flows recorded at main stream gauging stations are used in this model. Selected gauging stations are shown in Figure 2-11. Stream flows at adjacent site is also calculated by using specific run-off at where is necessary.

(3) Control factors

The water balance model assumes following control factors.

- Effective rainfall

  From 65% to 90% of monthly rainfall in simulation month are assumed to be effective for planted crop as shown below.

Effective Rainfall

(Unit: percent)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Effective Rainfall	90	90	80	75	75	75	75	75	65	65	80	90

- Return flow

  Irrigation water and rainfall not effectively used in irrigation area become return flow. This return flow is effective for reuse in downstream areas. In the simulation, 30 - 90% values of return flow rates by month are employed against total of flows and rainfalls into/on a sub basin.

- Irrigation efficiency

  Constant efficiencies are employed to represent influences of canal seepage, percolation, evaporation and operation losses. Values of 50 to 60% are assumed in the simulation and influences of the values are examined.

- Land preparation

  Land preparation water requirements are assumed as follows.

Wet season	280 mm
Dry season	350 mm

  Land preparation water is supplied continuously through the land preparation period.

- Consumptive use

  Consumptive use is defined as a water loss through evapotranspiration of crops. Amount of consumptive use is calculated from crop coefficient and potential evapotranspiration. Potential evapotranspiration used in the simulation is presented in Table 2-7.

(4) Water balance calculation

Water balance is calculated by sub-basin, taking account of water requirement based on the above-mentioned control factors and amount of available side flows. Minimum flow constraint is also considered at some particular location in river systems.

3.2.2 Study on Dam Operation

Dam operation under precise release control in dry season since 1978 have been simulated. For study of water resources in the basin from view-points of both demand and supply irrigated area and cropping pattern in the basin are applied as shown in Tables 2-10 and 2-11. The results of simulation study are as follows.

Satisfactory dam operation is entirely carried out to meet with water demands in the Chao Phraya Delta as judged from simulated water storage shown in Figure 2-12. In this figure, estimated dam operation presents the variation of water storage simulated by computer program model. In comparison with estimated dam operation and actual one, both variations of water storage are nearly same except at some years.

As these dams are consecutive storage dams, influence of excessive release partially contributes to long-term decrease of dry season crop area. Especially, excessive release in wet season in 1981 and May to July in 1986 is one of causes of decrease of dry season crop area in draught year since then.

Dam storage was decreased during wet season in 1979 till dry season in 1980. Side flows in this wet season account for 30% of that in normal year; equivalent to 20-year return period. Annual rainfall in Chao Phraya Delta was about 800 mm as compared with 1,000 to 1,200 mm in normal year. Therefore, wet season crop in 1979 was much more dependent upon the dam storage. Furthermore, a large volume of release was carried out to maintain 1.3 million rai in the dry season in 1980. It therefore becomes necessary to establish systems for annual crop and release planning in case of such draught years.

Comparison of monthly water flow at Nakhon Sawan in the simulation is shown in Figure 2-13.

2.3 Irrigation Water Use

2.3.1 Present Conditions of Water Resources

Water resources for Chao Phraya Delta are composed of water release controlled by both huge reservoirs, uncontrolled side flows and direct rainfall in the delta. Kiu Lom Reservoir in Wang River and other reservoirs in the basin only function to supply water to their own irrigation areas, and therefore do not help any water supply to the delta.

Amount of water resources from 1977 to 1986 for Chao Phraya Delta is shown as follows.

Amount of Water Resources

(unit: MCM)

Season	Release from Dams	Side Flow[*1]	Available Water
Wet[*2]	3,800	14,700	18,500
Dry[*2]	6,200	1,200	7,400
Total	10,000	15,900	25,900

Note: *1 ... Side flow at Nakhon Sawan and Rama VI Brrg.
*2 ... From July to December
*3 ... From January to June

Water release from dams amounts to 3,000 to 6,200 MCM or 25 to 92% of available water. Available water in Chao Phraya Delta are shown in Table 2-13 and Figure 2-14. Uncontrolled side flows from Yom, Nan and Ping rivers are also shown in Table 2-14.

Side flows are not expected during dry season especially from January to April, and most of irrigation water during this period is dependent on water release from the dams.

Meanwhile, water use conditions of water resources in current 10 years are as follows.

Season	Intake [*1]	Release [*2] Flow Constraints	Release [*2] Unavailable Release	Irrigated Area	Rainfall
	(MCM)	(MCM)	(MCM)	(10^6 rai)	(MCM)
Wet	6,700	2,000	10,760	6.1	8,900
Dry	4,200	2,000	1,060	2.7	3,900

Note: *1 ... Intake at Chainat and Rama VI Barrage.
*2 ... Release from Chao Phraya and Rama VI Dams.

Average available water at Nakhon Sawan and Rama VI Barrage is 7,400 MCM in dry season. Intake of 4,200 MCM is 57% of the above available water. Unavailable water released from Chao Phraya Dam and Rama VI barrage is only 1,060 MCM theoretically during dry season. Intake of 4,200 MCM corresponds to 0.6 lit/s/ha in dry season. It is considered that the amount of available intake water is at minimum level and water release is well controlled.

2.3.2 Water Balance

Relation between available water and water consumption in the delta is shown in Figure 2-17. In this figure, consumptive use and effective rainfall for crops are estimated in the simulation model. Seen from its relation, available water is fully consumed in dry season. Storage of river flow and rainfall in wet season is effective for extension of dry season crops. River flow in 1979 was less then that in the other years even in wet season. Water use condition of wet season in 1979 was the same as that of the other dry season.

Water balance study in the Delta from 1977 to 1986 are summarized as follows.

Season	Consumptive Use	Effective Rainfall	Water Requirement	Actual Intake	Estimated Storage[*1] in Delta
Wet	8,632	4,447	4,185	6,703	+ 2,518
Dry	5,709	893	4,816	4,184	- 632

Note: *1 ... Including unavailable groundwater flow

Results of yearly balance study are shown in Table 2-15. Seen from this balance study, it is considered that well-stored water during wet season is consumed in the next dry season.

Actual intake water in each irrigation area in the delta is calculated based on the amount of river flow at major regulators, as shown in Figure 2-18. Seen from relation between intake discharge and irrigation area, the intake discharge in water conservation area is less than in gravity irrigation area especially in dry season. Water intake in dry season is 0.2 - 0.5 lit/s/ha in the conservation area while 1.0 - 1.5 lit/s/ha in the gravity area, respectively. On the other hand, those in wet season are 0.2 - 0.7 lit/s/ha in the both areas because of effective rainfall. Amount of supplied water in 1985 is illustrated in Figures 2-19 and 2-20, as an example of water supply diagram.

Relation among actual water intake, rainfall and estimated consumptive use for planted crops in the lower west bank are shown in Figure 2-21. The relation indicates that water stored during wet season is effectively used for the next dry season crops.

Irrigation water is consisted of surface flow from head regulator, return flow from upper basin as a groundwater and storage water in the creeks which is well-developed in the water conservation area. Example of water level records in the creeks is shown in Figure 2-22.

2.3.3 Water Release from Reservoirs and Irrigated Area

Relation between water supply and rice yield in the delta has been studied for crop diversification and annual cropping plan.

Summary of water use conditions from 1978 to 1986 are shown in Tables 2-16 and 2-17. Tables 2-18 and 2-19 show relation between value of water supply, irrigated paddy area and rice yield. Supplied water including effective rainfall for six month is 1,826 m^3/rai and 1,850 m^3/rai in wet and dry season, respectively. Water supply is consisted of water release from dam, side flow and effective rainfall. Among them, water release is controllable and forecast of effective rainfall may be difficult under the present conditions.

Side flows are not controllable, however some portion of them may be effectively used of their run-offs are forecast and reservoir releases are so adjusted.

Components of irrigation water supply to cropping area are summarized as follows.

Crop	Average Irrigated Area (10^6 rai)	Irrigation Water Supply (m^3/rai) Effective Rainfall	Reservoir Release	Side Flow	Total
Wet Paddy	6.1	751	283	792	1,826
Dry Paddy	2.7	330	1,260	260	1,850

Note: (1) Wet paddy: from July to December
(2) Dry paddy: from January to June

On the other hand, components of paddy yield to water supply is estimated as follows.

Crop	Yield (kg/rai)	Component of Production Yield(kg/rai) Effective Rainfall	Reservoir Release	Side Flow
Wet Paddy	348	143	54	151
Dry Paddy	587	105	400	82

Note: Details are shown in Tables 2-20 and 2-21.

Those relation are also illustrated in Figure 2-23.

Taking into account of effects of water management activities, relation of water release and side flow to production yield is important. Both relations are as follows.

Crop	Water Supply (m^3/rai) Reservoir Release	Side Flow	Water Supply per Yield (m^3/kg) Reservoir Release	Side Flow	Total
Wet Paddy	283	792	0.81	2.28	3.09
Dry Paddy	1,260	260	2.15	0.44	2.59

Note: Details are shown in Table 2-22 and Figures 2-23 and 2-24.

Volumes of water released from reservoirs to yield rice production are 0.81 m^3/kg and 2.15 m^3/kg in wet and dry seasons, respectively.

Dry season paddy is almost dependent on reservoir release. Release for wet paddy is only supplemental. In 1979, however, reservoir release of 2.14 m^3/kg was supplied for wet paddy. In this year, water supply from reservoirs in wet season was extremely much and almost equal to that in dry season. In drought year, release operation at reservoirs in wet season are under the same situations as that in dry season. Annual cropping plan is therefore very useful for water release control.

2.3.4 Examination on Available Water

Judging from the present situation of irrigation water use, it is necessary for effective use of water resources to ease water stress to the dams in dry season by making better use of side-flows in wet season and return-flows in dry season.

Effective use of water resources, though the degree is much dependent on completeness of water management system, may be achieved by well equipped information management through improved monitoring/communication systems, which enables improved side-flow forecasting and easy and prompt understanding of water behaviors in project areas.

After the completion of improvement system, water use efficiency of side flow and within project area will be able to be raised by 5 to 10%, in accordance with extension of improvement until at main canal level.

Amount of availed water is estimated about 1,000 MCM, which enables additional some 80,000 ha of dry season irrigation, judging from the relation between the amount of water supply and irrigation area.

For realization of effective use of available water;

- Release operation of Bhumibol and Sirikit reservoirs be carried out in accordance with water release plan based on an annual cropping plan.

- Water operation be managed by making full use of improved monitoring/communication facilities.

- Amount of sideflow be forecasted based on developed software by using the introduced hardware.

CHAPTER 3 IMPROVEMENT PLAN OF WATER MANAGEMENT SYSTEM

3.1 Basic Concept for Improvement Plan

It may simply be said that purpose of water management is effective management on reservation, supply and use of water. Water management system is a large system of various activities to secure water sources, to supply water to users on prompt timing and in necessary volume as required, to secure conveniences and benefits by water and to control water uses in most efficient and effective manners.

There appears some factors which make operation of the current water management system difficult. Aside from factors such as natural phenomena (flood, drought, high tide, etc.), financing and human resources, followings may be pointed out. (See table 3-1)

- Both hard- and softwares for information flow sequences from sensing of information till operation through transmission, processing, judgement and instruction are not satisfactory.

- Water use facilities for irrigation and drainage in the delta are hose constructed tens of years ago, and the water duty for design of canal system is small as compared with modern design standard. Therefore, capacity of water use facilities now at work becomes insufficient when cropping pattern changes from traditional supplementary wet paddy irrigation to modern dry season irrigation.

- Neat control of water at rivers and canals is so difficult and complicated task due mainly to flow travel time lag caused by long reaches of canal network everywhere in the delta.

Therefore, it consequently requires maintenance and further improvement of the current water management system by lessening/eliminating these constraints in both hard- and soft-wares in step-wise manners from integrated and strategic viewpoints. Water management system will be divided into four categories, taking account of the above situations in the basin.

(1) Management of water resources

- Basin water management
- Water distribution management
  - i) Water release management
  - ii) Water distribution management to the target area
- On-farm management

(2) Management of water use facilities

(3) Institutional management

(4) Information management

Relation between water management category and management concept is shown in Figure 3-1.

3.2 Outlines of Improved Water Management System

3.2.1 Management of Water Resources

System diagram of water resources management in the Chao Phraya basin is described in Figure 3-2.

(1) Basin water management

In order to manage water resources in the basin, establishment of improved basin water management system furnished with the following basic idea is herein proposed.

- Chao Phraya and adjacent Mae Klong River basins are divided into 14 sub-basins and 5 sub-basins, respectively, taking account of Regional boundary of RID and natural boundary. Basin water management system for water resources will be considered on this sub-basion basis.

- Every development project in each sub-basin are reviewed and evaluated from view point of use of limited water resources in the whole basin.

- Basin development projects may affects the long-term trend of run-off discharge. From this view point, proper countermeasures for conservation of water resources are programmed.

- Water resources developments may cause serious natural and social problems. Allocation of developed water resources is well coordinated.

(2) Water distribution management

1) Water release management from resources

In order to plan annual cropping schedule and water release from the both reservoirs, data management system are improved for provision of the following data/information.

- Records of planted area, yield, amount of water release and intake and other hydrology data

- Past trends of reservoir storage and side flow

- Forecast side flow and storage or reservoirs on the basis of planned annual cropping schedule.

2) Water distribution management to project area

In order to properly distribute available water to project areas through major regulators, following activities are carried out at management levels.

- Forecasting of water demand and reporting to RID Head Office.

- Water allocation by RID Head office supported by use of improved data management system.

- RID Head office requests amount of water release to EGAT, and instructs distribution major regulators through Regional offices as same as present.

- Head office monitors actual situation of water distribution in the delta by using the improved monitoring system.

System formation of the above-mentioned water distribution management is shown in Figure 3-3.

3) Water distribution within the project area

In order to secure equitable distribution of water within a project area, improved water management is as follows.

- Irrigation water is precisely distributed by each section or zone defined by RID. Project office adjusts water allocation among sections or zones for the equitability.

- Calculation of water demand is made by each zone. Forecast water demand and observed intake discharge are recorded and utilized for the next adjustment.

(3) On-farm management

Improved management shall be that for precise control of water and water use facilities by beneficiaries in conformity with detailed provisions of guidelines for water operation and O & M of water use facilities. Such guidelines will firstly be established.

3.2.2 Management of water use facilities

In order to meet requirements for water management, protection and improvement of water use facilities and their functions from deterioration are so important that improved management of these facilities shall be in the following manners.

- To employ an improved system for data custody and retrieval of information on any water use facilities.

- To identify needs for maintenance/rehabilitation/ improvement of water use facilities by use of the above retrieval system and in accordance with some guidelines on standard level of functions of facilities to be equipped with.

- To formulate implementation of maintenance/rehabilitation/ improvement works of water use facilities in accordance with some criteria for improvement and by taking account of other constraints in practical ways.

3.2.3 Institutional management

Water management is barely significant if inter-related activities of concerned organization are not systematically performed. Improved management shall be in the following manners.

- Improvement in quality of activities at levels of concerned organizations.

- Improvement in equitable quality of activities among organizations concerned in conformity with some guidelines on standard quality of activities.

For achievement of the above, training activities are programed and carried out to the levels of organizations. some educational and training activities composed of the following contents will also be programed for establishment and encouragement of farmers' organization.

- Present situation of limited water resources and water use in the delta.

- Optimum water use by growing stage of crop.

- Proper method for repair and maintenance of farm ditch and field structures.

- General information about agriculture.

3.2.4 Information management

Improved management of information includes management of not only those for the current water allocation/operation but also those of water use facilities and agro-socio-economy.

The improved system is composed of a cental system at the Head office, sub-systems at Regional office and division of the Head office level and terminal systems at project office and division of the Regional office level. The system is designed so as that any level of component system can approach to any information of different level or of different office through an universal Information Bus Line (IBL).

3.2.5 Water management level

Improvement of overall water management involves many fields of works and requires time, financing, planning and implementation programing. Target levels of improvement may differ by significance of improvement subjects. Therefore, a concept of "Water management Level" is herein proposed for formulation of improved water management. The water management level demotes target level of improvement ranging from Level 0 (zero) to level 4 as follows.

Level 0 implies continuation of the present activities without substantial changes in water operation activities and O & M of water use facilities.

Level 1 implies improvement of the present communication system at basin level, while improvement of other systems/activities is suspended.

Level 2 implies introduction of improved monitoring system until at main canal system level in addition to the improvement of Level 1.

Level 3 implies improvement of water use facilities of canal systems and overall water management system until at FTO level.

Level 4 implies improvement of overall water management system until at on-farm level including implementation of intensive land consolidation.

The above 4 levels of improved water management are thus proposed to formulate ways to the final goal of "Level 4" for the lower level. It may be formulated in a way that several target levels of improvement for the respective improvement components are combined to ease various constraints.

Table 2-1 NON-EXCEEDING PROBABILITY OF ANNUAL RAINFALL (1)

Unit ; mm

Station		Return Period (year) 2	5	10	20	50	100	200
Upper Ping								
Chiang Mai	(07013)	1,173	995	906	834	756	705	659
"	(07182)	962	842	786	742	696	667	641
"	(07252)	1,529	1,128	945	807	664	575	498
Lamphun	(17062)	951	824	768	726	683	656	633
Wang								
Lampang	(16013)	1,028	879	812	762	709	677	649
Lower Ping								
Tak	(63042)	1,374	1,167	1,062	977	683	821	765
Yom								
Sukhothai	(59121)	1,136	960	868	793	709	654	603
Upper Nan								
Nan	(28102)	1,234	1,068	991	932	870	831	797
"	(28131)	1,064	903	824	761	694	650	611
Uttaradit	(70151)	1,224	1,039	953	888	820	778	741

Note : Annual Rainfall from 1952 to 1986

Table 2-1 NON-EXCEEDING PROBABILITY OF ANNUAL RAINFALL (2)

Unit ; mm

Station	Return Period (year)						
	2	5	10	20	50	100	200
Lower Nan							
Uttaradit (70013)	1,392	1,227	1,147	1,084	1,017	974	936
Phichit (38012)	1,379	1,110	986	892	794	732	679
Nakhon Sawan							
Nakhon Sawan(26013)	1,178	894	758	652	539	466	402
Pasak							
Phetchabun (36013)	1,093	936	860	801	738	696	662
Chaophraya Delta							
Chai Nat (04361)	926	792	731	686	638	609	583
Ang Thong (01012)	1,225	1,068	996	941	883	847	816
Ayutthaya (42012)	1,063	840	745	677	610	569	534
Bangkok (41013)	1,463	1,236	1,124	1,034	935	871	814
Samut Sakhon(52012)	1,271	1,058	951	864	769	707	651
Nakhon Pathom (23012)	1,102	873	755	658	552	480	417
Suphan Buri(60022)	918	719	627	557	485	439	401

Note : Annual Rainfall from 1952 to 1986)

Table 2-2 SUMMARY OF RUN-OFF IN CHAO PHRAYA BASIN

Station	Catchment Area (km^2)	Average Annual Run-off (MCM)	Specific Annual Run-off (mm)	Basin Rainfall
Inflow to Dam				
Bhumibol	26,400	6,090	230	1,170
Sirikit	13,100	5,800	440	1,180
Kue Lom	2,700	630	230	1,080
Dam Release				
Bhumibol	-	5,590	-	-
Sirikit	-	5,130	-	-
Discharge at Nakhon Sawan				
Side Flow	71,000	13,600	192	1,200
Dam Release	39,500	10,720	-	-
Sub-total	110,600	24,320		
Pasak River	14,400	2,090	140	1,110
Available Water at Nakhon Sawan		26,410		

Note : Estimation based on run-off from 1972 to 1986, because operation of Sirikit Dam started on Apr. in 1971. But average rainfall calculated from 1952 to 1986.

Table 2-3 NON-EXCEEDING PROBABILITY OF ANNUAL RUN-OFF

Unit : MCM

Station	Catchment Area (Km^2)	Return Period (year)						
		2	5	10	20	50	100	200
Upper ping (P19A)	14,023	2,975	2,232	1,959	1,778	1,614	1,522	1,449
Upper Nan (N35)	10,335	5,377	4,342	3,884	3,544	3,199	2,987	2,807
Yom (Y3A)	13,583	2,540	1,728	1,376	1,116	855	697	563
Lower Wang (W4A)	10,507	1,017	668	533	441	354	305	265
Pasak (S9)	14,374	2,324	1,509	1,193	976	771	655	560

Note : Annual run-off from 1967 to 1986

Table 2-4 PROBABILITY OF SIDEFLOW AT NAKHON SAWAN IN WET SEASON

Unit : MCM

Return Period (year)	Probability of non-exceedance	Probability of exceedance
2	11,583	11,583
5	7,489	17,417
10	5,862	21,396
20	4,728	25,284
50	3,642	30,433
100	3,015	34,400
200	2,501	38,449

Note : Sideflow from 1967 to 1986 in wet season (Jul - Dec)

Table 2-5 SEASONAL INFLOW TO RESERVOIRS

Unit: MCM

Year	Bhumibol Dam			Sirikit Dam			Both Dam		
	Nov - Mar	Apr - Oct	Total	Nov - Mar	Apr - Oct	Total	Nov - Mar	Apr - Oct	Total
1972/73	1,623	8,192	9,815	659	5,942	6,601	2,282	14,134	16,416
1973/74	1,208	4,575	5,783	766	3,726	4,492	1,974	8,301	10,275
1974/75	2,432	7,128	9,560	703	7,600	8,303	3,135	14,728	17,863
1975/76	1,808	3,648	5,456	944	5,280	6,224	2,752	8,928	11,680
1976/77	1,543	4,345	5,888	1,013	3,510	4,523	2,556	7,855	10,411
1977/78	1,320	6,181	7,501	727	5,800	6,527	2,047	11,981	14,028
1978/79	789	2,962	3,751	671	3,233	3,904	1,460	6,195	7,655
1979/80	206	5,398	5,604	457	5,725	6,182	663	11,123	11,786
1980/81	960	4,157	5,117	592	7,066	7,658	1,552	11,223	12,775
1981/82	1,556	4,616	6,172	770	4,251*	5,021	2,326	8,867	11,193
1982/83	801	3,172	3,973	607*	4,615*	5,222	1,408	7,787	9,195
1983/84	2,019	3,329	5,348	886*	5,712	6,598	2,905	9,041	11,946
1984/85	706	3,742	4,448	734	4,479	5,213	1,440	8,221	9,661
1985/86	2,279	3,163	5,442	884	4,014	4,898	3,163	7,177	10,340
1986/87	616	N. A.	–	543	n. a.	–	1,159	n. a.	–
Average	1,375	4,615	5,990	744	5,068	5,812	2,119	9,683	11,802

Table 2-6 CATCHMENT AREA BY RIVER BASIN

Name	Basin Number	Catchment Area (sq. km.)
Chao Phraya Basin		
Ping Basin		
Upstream of Bhumipol	(1)	26,400
Downstream of Bhumipol	(4)	13,120
Wang Basin		
Upstream of Kiu Lom	(2)	2,700
Downstream of Kiu Lom	(3)	7,810
Yom Basin		
Upstream basin	(5)	9,190
Downstream basin	(6)	11,920
Nan Basin		
Upstream of Sirikit	(7)	13,200
Downstream of Sirikit	(8)	26,230
Sub-total (at Nakhon Sawan)		110,570
Pasak Basin	(10)	13,780
Chao Phraya		
Nakhon Sawan	(9)	6,860
Upper East	(11)	8,060
Lower East	(12)	6,840
Upper West	(13)	6,290
Lower West	(14)	4,280
Sub-total		32,330
Total (Chao Phraya Basin)		156,680

Table 2-7 MONTHLY POTENTIAL EVAPOTRANSPIRATION IN EACH BASIN

Unit ; mm / month

Basin	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		Month											
①	Chaing Mai	104	136	172	188	164	143	135	122	124	121	109	93
②	Lampang	113	145	182	198	170	152	147	133	128	123	114	101
③	- do -						- do -						
④	Nakon Sawan	132	164	201	208	179	162	152	141	133	133	130	122
⑤	Phrae	119	150	192	208	180	157	149	135	131	128	120	107
⑥	Phitsanulok	112	138	168	181	162	143	136	126	127	129	119	106
⑦	Phrae	119	150	192	208	180	157	149	135	131	128	120	127
⑧	Phitsaunlok	112	138	168	181	162	143	136	126	127	129	119	106
⑨	Nakon Sawan	132	164	201	208	179	162	152	141	133	133	130	122
⑩	- do -						- do -						
⑪	Lopburi	143	165	197	201	175	160	150	139	134	137	138	133
⑫	Don Muang	137	154	179	180	164	156	149	142	141	137	133	128
⑬	Suphan Buri	148	165	200	210	187	176	167	156	145	145	144	139
⑭	Don Mung	137	154	179	180	164	167	149	142	141	137	133	128

Table 2-9 INVENTORY OF MAJOR DAMS AND REGULATORS

Name of Dam	Catchment Area (km²)	Average Annual Inflow (MCM)	Storage Capacity Gross (MCM)	Storage Capacity Effective (MCM)	Purposes*
Bhunibol	26,400	8,600	12,200	8,600	I, F, P
Sirikit	13,100	7,000	10,550	8,800	I, F, P
Kiu Lom	2,700	570	112	106	I, F
Khao Laem	3,700	5,200	7,500	4,800	I, F, P
Srinagarind	10,900	4,600	17,700	7,500	I, F, P
Kra Sieo	1,200	165	390	200	I, F
Mae Ngat	1,300	400	n. a.	n. a.	I, F, P
Mae Kuang	570	250	n. a.	n. a.	I, F

Note * I ; Irrigation, F ; Flood Control, P ; Power Generation

Table 2-8 INVENTORY OF MAJOR REGULATORS IN THE BASIN

Name of Diversion Weir	Catchment Area (km²)	Storage Capacity (MCM)	Design Discharge (m³/s)
Chainat	n. a.	130	3,300
Rama VI Barrage	n. a	n. a	35
Vajiralongkom	25,600	6	n. a.
Nare suan	n. a.	n. a.	n. a.

Table 2-10 PADDY PLANTED AREA IN CHAO PHRAYA DELTA

(Unit = 10^3 ha)

Year	Upper East		Upper West		Lower East		Lower West		Total	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
1976	212.4	6.5	357.1	99.6	315.7	80.6	91.9	134.1	977.1	320.8
1977	210.9	16.0	352.4	114.3	321.6	102.9	103.6	122.9	988.5	356.1
1978	220.0	12.3	348.1	76.6	306.4	107.9	94.0	142.2	968.5	339.0
1979	208.9	39.2	338.4	170.4	350.6	120.8	73.8	152.9	971.7	483.3
1980	212.1	0.5	351.2	18.4	349.6	55.4	69.7	137.1	982.6	211.4
1981	212.8	34.3	345.5	173.8	336.6	145.7	89.2	149.9	984.1	503.7
1982	212.0	39.0	336.6	195.2	340.7	144.7	90.6	153.0	979.9	531.9
1983	211.2	20.7	330.0	203.1	325.5	144.1	113.4	146.6	980.1	514.6
1984	213.1	48.7	341.9	176.6	324.3	132.5	122.6	156.6	1,001.9	514.4
1985	214.6	29.7	335.7	161.9	318.9	125.8	139.3	144.2	1,008.5	461.6
1986	196.4	26.0	335.4	132.7	314.1	121.2	135.2	141.4	981.1	421.3

Note : Lower East = Nakhon Luang, Pasak Tai, Rangsit Nua, Rangsit Tai, Khlong Dan, Phra Ong Chai-ya-nu-chit

Lower West = Chao-ched-Bang-Yihon, Phraya Banlue, Phra Phimon, Phasi Charoen, Bang Ban

Upper East = Maharat, Manorom, Chong Khae, Khoke Kathiem, Roeng Rang

Upper West = Phonlathep, Thabote, Sam Chook, Pho Phaya, Don Chedi, Borommathat, Channasutr, Yang Manee, Phak Hai

Table 2-11 IRRIGATED AREA BY RIVER BASIN

(Unit : 10^3 ha)

	Upper Ping	Wang	Upper Yom	Upper Nan	Lower Ping	Lower Yom	Lower Nan	Sakae-krang	Pasak
Region	I	I	I	II	III	III	III	VII	III, VIII
Basin Number	1	3	5	7	4	6	8	9	10
Year									
1976	139	16	37	17	29	6	69	3	22
1977	143	16	38	17	47	10	84	14	22
1978	144	16	38	17	47	10	85	14	24
1979	144	16	38	17	47	10	85	14	24
1980	144	16	38	18	50	10	85	14	24
1981	145	25	38	18	53	10	85	14	31
1982	149	25	38	18	53	10	85	30	31
1983	149	25	38	18	53	10	85	30	32
1984	150	25	39	18	57	10	85	30	32
1985	158	26	39	18	73	10	167	30	32
1986	158	26	39	18	73	17	167	30	32

Source : Water Resources Development in Thailand completed to the end of 1985 and Under construction in 1986 (RID)

Table 2-12 COMPARISON BETWEEN REQUESTED RELEASE AND ACTUAL RELEASE FROM BOTH DAMS

Unit = MCM

Month	1979		1980		1981		1982		1983		1984		1985		1986	
	Request by RID	Actual Release	Request by RID	Actual Release	Request by RID	Actual Release	Request by RID	Actual Release	Request by RID	Actual Release	Request by RID	Actual Release	Request by RID	Actual Release	Request by RID	Actual Release
Jan.	295	794	0	535	156	639	469	713	813	858	276	323	786	737	333	406
Feb.	921	956	466	461	879	921	1,300	1,209	1,301	1,251	1,192	1,142	1,178	1,169	1,175	1,178
Mar.	1,590	1,660	683	616	1,343	1,287	1,747	1,663	1,671	1,658	1,668	1,609	1,690	1,657	1,680	1,647
Apr.	1,723	1,618	604	586	1,438	1,480	1,496	1,428	1,615	1,673	1,698	1,501	1,547	1,510	1,540	1,433
May	1,180	1,447	447	545	782	1,332	1,074	1,129	1,312	1,260	968	1,001	989	962	783	1,196
Jun.	503	1,011	433	353	0	1,333	736	759	458	645	259	456	579	489	229	1,221
Jul.	734	1,234	670	366	0	548	1,331	1,251	1,050	969	778	648	613	469	1,172	1,078
Aug.	1,464	1,337	0	265	60	1,187	1,702	1,428	631	506	1,166	1,053	488	487	704	732
Sep.	828	847	0	329	0	719	674	434	34	165	873	913	441	350	514	537
Oct.	884	938	0	342	542	649	0	357	0	59	389	272	60	108	1,063	908
Nov.	1,683	1,409	0	320	700	861	206	607	0	73	726	731	36	147	1,447	1,280
Dec.	886	853	0	417	161	515	200	495	0	79	233	273	0	200	399	445
Total	12,691	14,104	3,303	5,137	6,061	11,471	10,935	11,473	8,885	9,196	10,226	9,922	8,407	8,285	11,039	12,061

Note ; ▭ indicates much difference between requested release and actual one

Table 2-13 AVAILABLE WATER IN CHAO PHRAYA DELTA

Unit : MCM

Year	Wet Season				Dry Season			
	Run-off except Dam	Release from Dam *1	Discharge at Nakhon Sawan	Pasak River *2	Run-off except Dam	Release from Dam *1	Discharge at Nakhon Sawan	Pasak River *2
1967	10,849	3,569	14,418	831	N.A.	N.A.	N.A.	N.A.
1968	6,923	3,060	9,983	911	1,944	2,663	4,607	219
1969	14,786	2,216	17,002	1,786	667	2,349	3,016	115
1970	27,299	3,430	30,729	2,610	1,151	3,473	4,624	113
1971	11,914	6,790	18,731	2,541	1,712	3,691	5,403	226
1972	5,651	5,095	10,746	1,968	-	4,762	4,688	210
1973	12,567	4,189	16,756	974	876	4,318	5,194	168
1974	10,623	4,824	15,447	1,125	143	5,632	5,775	108
1975	21,063	7,451	28,514	2,980	841	5,836	6,677	147
1976	15,692	6,022	21,714	2,649	1,146	8,273	9,419	173
1977	7,846	6,131	13,977	1,233	436	8,189	8,625	184
1978	21,028	3,636	24,664	4,950	492	4,961	5,453	140
1979	4,419	6,618	11,037	714	1,418	7,456	8,874	234
1980	21,524	2,039	23,563	2,675	1,750	3,097	4,847	143
1981	12,694	4,479	17,173	2,138	1,268	6,825	8,093	176
1982	8,065	4,572	12,637	2,695	362	6,901	7,263	191
1983	14,798	1,851	16,649	2,454	69	7,340	7,409	148
1984	7,520	3,889	11,409	2,443	1,291	6,059	7,350	308
1985	14,735	1,735	16,470	3,221	500	6,516	7,016	263
1986	5,344	5,578	10,922	857	2,070	7,077	9,147	294
Average	12,768	4,358	17,126	2,087	955	5,548	6,503	187

Note : *1 = Operation of both Dam had been started on July in 1971.
Before 1971, only Bhumibol Dam had been operated.

*2 = Discharge be estimated until 1972

Table 2-14 SIDEFLOW IN WET SEASON AT NAKHON SAWAN

Unit : MCM

Year	Observed Run-off Discharge[*1] Yom	Nan	Ping	Total	Sideflow at Nakhon Sawan
1967	1,880	1,949	1,431	5,260	10,849
1968	863	1,405	1,267	3,535	6,923
1969	1,391	2,750	3,338	7,479	14,786
1970	3,755	3,406	4,175	11,336	27,299
1971	3,924	3,173	2,779	9,876	11,941
1972	1,448	1,148	1,908	4,504	5,651
1973	3,970	2,989	3,525	10,484	12,567
1974	2,524	2,522	2,893	7,939	10,623
1975	3,650	5,562	3,551	12,763	21,063
1976	2,249	4,686	2,633	9,568	15,692
1977	2,068	3,322	1,722	7,112	7,846
1978	3,940	6,327	2,650	12,917	21,028
1979	801	1,898	1,077	3,776	4,419
1980	2,423	5,732	2,132	10,287	21,524
1981	3,585	4,154	2,253	9,992	12,694
1982	1,212	3,144	1,085	5,441	8,065
1983	2,232	3,670	2,929	8,831	14,798
1984	1,883	2,529	1,103	5,515	7,520
1985	2,105	5,413	1,857	9,375	14,735
1986	1,571	2,413	1,513	5,497	5,344
Average	2,374	3,410	2,291	8,075	12,768

Note : *1 = Observation station are as follows

Yom .... Y3A (13,580 km^2)

Nan .... N7A - N12 (13,430 km^2)

Ping ... P7 - P12 (16,300 km^2)

Table 2-15 WATER BALANCE STUDY IN CHAO PHRAYA DELTA

Year	Season	Irrigated Area	Actual		Calculated			
			Intake	Release	Consumptive Use	Effective Rainfall	Require -ment	Storage
		(10^6rai)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
1977	W	6.2	7,790	6,299	8,652	3,060	5,592	2,198
1978	D	2.1	2,772	2,217	4,597	855	3,742	−970
	W	6.0	6,010	24,771	8,460	3,554	4,906	1,104
1979	D	3.0	5,343	3,268	6,142	816	5,326	17
	W	6.1	7,118	3,890	8,553	2,469	6,084	1,034
1980	D	1.3	1,967	3,370	3,183	432	2,751	−784
	W	6.1	6,189	22,507	8,573	4,571	4,002	2,187
1981	D	3.1	4,535	3,627	6,375	1,295	5,080	−545
	W	6.1	7,319	15,009	8,645	5,241	3,404	3,915
1982	D	3.3	4,428	2,750	6,679	1,263	5,416	−988
	W	6.1	7,374	8,747	8,621	3,797	4,824	2,550
1983	D	3.2	4,963	2,413	6,493	535	5,958	−995
	W	6.1	3,387	20,332	8,609	7,227	1,382	2,005
1984	D	3.2	4,906	2,636	6,501	910	5,591	−685
	W	6.2	7,798	6,528	8,759	4,834	3,961	3,837
1985	D	2.8	4,343	2,424	5,930	827	5,103	−760
	W	6.3	7,054	14,701	8,820	4,933	3,887	3,167
1986	D	2.7	4,398	4,802	5,479	1,106	4,373	25
	W	6.1	6,990	4,813	8,588	4,782	3,806	3,184
Average	D	2.7	4,184	3,056	5,709	893	4,816	−632
	W	6.1	6,703	12,760	8,632	4,447	4,185	2,518

Table 2-16 CURRENT WATER USE CONDITION IN WET SEASON

Unit : MCM

Year	Available Water			Water use in Delta		Estimated*3
	Dam Release	Side*1 Flow	Total	Actual Intake	Actual Release*2	EFF. Rainfall in Delta
1978	3,636	25,978	29,614	6,010	24,771	3,554
1979	6,618	5,133	11,751	7,118	3,890	2,469
1980	2,039	24,199	26,238	6,189	22,507	4,571
1981	4,479	14,832	19,311	7,319	15,009	5,241
1982	4,572	10,760	15,332	7,374	8,747	3,797
1983	1,851	17,252	19,103	3,387	20,332	7,227
1984	3,889	9,963	13,852	7,798	6,528	4,834
1985	1,735	17,956	19,691	7,054	14,701	4,933
1986	5,578	6,201	11,779	6,990	4,813	4,782
Average	3,822	14,697	18,519	6,582	13,478	4,601

Note

(1) *1 : Accumulated un-controlled flow at Nakhon Sawan and Pasak

(2) *2 : Released water from Chao Phraya Dam, Rama VI, Phophaya and Pakhai Regulators.

(3) *3 : Effective Rainfall

(4) Wet season from Jul. to Dec.

Table 2-17 CURRENT WATER USE CONDITION IN DRY SEASON

Unit : MCM

Year	Available Water			Water Use in Delta		Estimated*3
	Dam Release	Side*1 Flow	Total	Actual Intake	Actual Release*2	EFF. Rainfall in Delta
1978	4,961	632	5,593	2,772	2,217	855
1979	7,456	1,652	9,108	5,343	3,268	816
1980	3,097	1,893	4,990	1,967	3,370	432
1981	6,825	1,444	8,269	4,535	3,627	1,295
1982	6,901	553	7,454	4,428	2,750	1,263
1983	7,340	217	7,557	4,963	2,413	535
1984	6,059	1,599	7,658	4,906	2,636	910
1985	6,516	763	7,279	4,343	2,424	827
1986	7,077	2,364	9,441	4,398	4,802	1,106
Average	6,248	1,235	7,483	4,184	3,056	893

Note :

(1) *1 : Accumulated un-controlled flow at Nakhon Sawan and Pasak

(2) *2 : Released water from Chao Phraya Dam , Rama VI, Pho phaya and Pakhai Regulators

(3) *3 : Effective Rainfall

(4) Dry season from Jan. to Jun.

Table 2-18 WATER USE AND YIELD IN WET SEASON

Year	Planted Area (10^6 rai)	Yield per rai (kg/rai)	Actual*[1] Intake (MCM)	Water use in Delta: Effective Rainfall (MCM)	Water use in Delta: Total (MCM)	Water use per rai (m^3/rai)	Yield per Water use (kg/m^3)
1978	6.0	295	6,010	3,554	9,564	1,594	0.185
1979	6.1	307	7,118	2,469	9,587	1,572	0.195
1980	6.1	340	6,189	4,571	10,760	1,764	0.193
1981	6.1	352	7,319	5,241	12,560	2,060	0.171
1982	6.1	358	7,374	3,797	11,171	1,831	0.196
1983	6.1	368	3,387	7,227	10,614	1,740	0.211
1984	6.2	364	7,798	4,834	12,632	2,037	0.179
1985	6.3	364	7,054	4,933	11,987	1,903	0.191
1986	6.1	387	6,990	4,782	11,772	1,930	0.201
Average	6.1	348	6,582	4,601	11,183	1,826	0.191

Note

(1) *[1] : Except release from Chao Phraya Dam, Rama VI, Phophaya and Pakhai Regulator

(2) Wet season from Jul. to Dec.

Table 2-19 WATER USE AND YIELD IN DRY SEASON

Year	Planted Area (10^6 rai)	Yield per rai (kg/rai)	Water use in Delta: Actual*[1] Intake (MCM)	Water use in Delta: Effective Rainfall (MCM)	Water use in Delta: Total (MCM)	Water use per rai (m^3/rai)	Yield per Water use (kg/m^3)
1978	2.1	545	2,772	855	3,627	1,727	0.316
1979	3.0	556	5,343	816	6,159	2,053	0.271
1980	1.3	546	1,967	432	2,399	1,845	0.296
1981	3.1	633	4,535	1,295	5,830	1,880	0.337
1982	3.3	582	4,428	1,263	5,691	1,725	0.337
1983	3.2	560	4,963	535	5,498	1,718	0.326
1984	3.2	623	4,906	910	5,816	1,818	0.343
1985	2.8	624	4,343	827	5,170	1,846	0.338
1986	2.7	612	4,398	1,106	5,504	2,039	0.300
Average	2.7	587	4,184	893	5,077	1,850	0.318

Note

(1) *[1] : Except release from Chao Phraya Dam, Rama VI, Phophaya and Pakhai Regulator

(2) Dry season from Jan. to Jun.

Table 2-20 RELATION BETWEEN WATER SUPPLY AND YIELD IN DELTA (WET SEASON)

Year	Planted Area (10^6 rai)	Component of water supply: Effective Rainfall (m^3/rai)	Component of water supply: Dam Release (m^3/rai)	Component of water supply: Side Flow (m^3/rai)	Component of water supply: Total Supply per rai (m^3/rai)	Component of Yield: Effective Rainfall (kg/rai)	Component of Yield: Dam Release (kg/rai)	Component of Yield: Side Flow (kg/rai)	Component of Yield: Total Yield per rai (kg/rai)
1978	6.0	592	123	879	1,594	109	23	163	295
1979	6.1	404	658	510	1,572	79	129	99	307
1980	6.1	749	79	936	1,764	144	15	181	340
1981	6.1	860	278	922	2,060	147	48	157	352
1982	6.1	622	360	849	1,831	122	70	166	358
1983	6.1	1,185	54	501	1,740	251	11	106	368
1984	6.2	780	353	904	2,037	139	63	162	364
1985	6.3	783	99	1,021	1,903	150	19	195	364
1986	6.1	784	543	603	1,930	157	109	121	387
Average	6.1	751	283	792	1,826	143	54	151	348

Note

*1 : Dam release and side flow be estimated, based on the proportion of available water to the actual intake.

Table 2-21 RELATION BETWEEN WATER SUPPLY AND YIELD IN DELTA (DRY SEASON)

Year	Planted Area (10^6 rai)	Component of Water Supply: Effective Rainfall (m^3/rai)	Dam*[1] Release (m^3/rai)	Side*[1] Flow (m^3/rai)	Total Supply per rai (m^3/rai)	Component of Yield: Effective Rainfall (kg/rai)	Dam Release (kg/rai)	Side Flow (kg/rai)	Total Yield per rai (kg/rai)
1978	2.1	407	1,171	149	1,727	128	370	47	545
1979	3.0	272	1,458	323	2,053	74	395	87	556
1980	1.3	332	940	573	1,845	98	278	170	546
1981	3.1	418	1,206	256	1,880	141	406	86	633
1982	3.3	382	1,244	99	1,725	129	420	33	582
1983	3.2	167	1,506	45	1,718	54	491	15	560
1984	3.2	284	1,213	321	1,818	97	416	110	623
1985	2.8	295	1,388	163	1,846	100	469	55	624
1986	2.7	410	1,222	407	2,039	123	367	122	612
Average	2.7	330	1,260	260	1,850	105	400	82	587

Note

*[1] : Dam release and side flow be estimated, based on the proportion of available water to the actual intake.

Table 2-22 WATER SUPPLY PER YIELD IN WET SEASON

Year	Water Supply			Yield per rai	Water Supply per Yield		
	Dam*[1] Release (m^3/rai)	Side*[1] Flow (m^3/rai)	Total Supply (m^3/rai)	(kg/rai)	Dam Release (m^3/kg)	Side Flow (m^3/kg)	Total Yield (m^3/kg)
1978	123	879	1,002	295	0.42	2.98	3.40
1979	658	510	1,168	307	2.14	1.66	3.80
1980	79	936	1,015	340	0.24	2.75	2.99
1981	278	922	1,200	352	0.79	2.62	3.41
1982	360	849	1,209	358	1.01	2.37	3.38
1983	54	501	555	368	0.15	1.36	1.51
1984	353	904	1,257	364	0.97	2.48	3.45
1985	99	1,021	1,120	364	0.27	2.81	3.08
1986	543	603	1,146	387	1.40	1.56	2.96
Average	283	792	1,075	348	0.81	2.28	3.09

Note : *[1] = Dam release and sideflow be estimated, based on the proportion of available water to the actual intake.

Table 2-23 WATER SUPPLY PER YIELD IN DRY SEASON

Year	Water Supply			Yield per rai	Water Supply per Yield		
	Dam*1 Release (m^3/rai)	Side*1 Flow (m^3/rai)	Total Supply (m^3/rai)	(kg/rai)	Dam Release (m^3/kg)	Side Flow (m^3/kg)	Total Yield (m^3/kg)
1978	1,171	149	1,320	545	2.15	0.27	2.42
1979	1,458	323	1,781	556	2.62	0.58	3.20
1980	940	573	1,513	546	1.72	1.05	2.77
1981	1,206	256	1,462	633	1.91	0.40	2.31
1982	1,244	99	1,343	582	2.14	0.17	2.31
1983	1,506	45	1,551	560	2.69	0.08	2.77
1984	1,213	321	1,534	623	1.95	0.51	2.46
1985	1,388	163	1,551	624	2.22	0.26	2.48
1986	1,222	407	1,629	612	2.00	0.66	2.66
Average	1,260	260	1,520	587	2.15	0.44	2.59

Note : *1 = Dam release and side flow be estimated, based on the proportion of available water to the actual intake

Table 3-1 COMPARISON TABLE ; PRESENT AND IMPROVED WATER MANAGEMENT SYSTEM

Management Category	Present Water Management System	Problems in the Present System	Improved Water Management System	Strategies by the Study Team
[A. MANAGEMENT OF WATER RESOURCES]				
(1) Basin Management	– No mutual coordination in management between individual projects	– Shortage of available water resources	– Establishment of a system to survey, research and evaluate development/conservation of water resources in the basin – Coordination and recommendation activities in accordance with outcomes of analyses of the system	– Preparation of framework of the system formation – Preparation of basin-wide water balance simulation model – Recommendation of projects to prevent soil erosion – Preliminary study on new water resources development
(2) Distribution Management				
a) Reservoir Release Management	– Planning of dry season cropping area from reservoir storages at the end of wet season – Irrigation of whole areas in wet season	– Decrease of cropping area in drought year	– Reservoir operation in accordance with annual cropping plan derived from statistical analyses of hydrology and information of farming/agriculture	– Preliminary analyses and to identify future direction (Crop Diversification/Information Center)
b) Distribution Management in the Delta (See "B")				
c) Distribution Management in Project Area	– Judgment by experience	– Improper distribution – Excessive intake – Partial inundation damage	– A system to proceed from prediction, observation till verification at management levels – Data processing by management purposes and by groups of computer application programs	– Preparation of framework – Recommendation for implementation of Model Project
(3) On-farm Management	– Empirical management – Individual management	– Operation loss by poor on-farm facilities and their management	– Preparation of manual for proper diversion and management of on-farm facilities – Implementation of management by the manuals	– Preparation of guidelines to establish manuals – Proposal for Model Project
[B. INFORMATION MANAGEMENT: Ref above (2)]				
(1) Reservoir Release and Distribution Management in Project Area				
a) Measurement	– Water level/flow, rainfall	– Calibration of water level-flow – Error data/information	– Measurement of water quality, soil moisture/water logging – Automatic measurement of a part of them	– Preparation of observation network improvement plan
b) Collection	– Voice communication by radio or telephone	– Error by insufficient communi. system – Delay by busy line	– By improved system by voice communication – Partial introduction of automatic collection system	– Preparation of monitoring/communi. system improvement plan
c) Handling/filing	– Manual processing and hand writing onto file – Partially computerized	– Not systematic to do with processing	– Systematic compilation of data by purpose – Data management system by Data-Base	– Preparation of master plan for improved data management system
d) Processing	– Empirical – Centralized by use of RID's simulation model	– Error of judgment – Voluminous data compilation – Delay by long computer run-time	– Decentralized at project office level – Processing by purposes and by groups of computer application programs	– Preparation of plan for development of computer application programs – Preparation of supporting programs for the present simu. model
e) Instruction and Operation	– Voice communi. by radio and telephone – Manual operation	– Information error and instruction delay by communi. system	– Quick communi. by improvement of communi. system for instruction	– Preparation of plan for improvement of monitoring/communi. system
f) Monitoring/verification	– Manual graphic board at Head Office without veri. system	– Difficulty in proper water distribution	– Introduction of display panel system and verification system	– Development of softwares for use of display panel system
[C. MANAGEMENT OF FACILITIES]	– Partial repair/rehabili. by individual project management	– Functional deterioration	– Preparation of operation and maintenance manual for the management	– Preparation of guidelines to establish manuals – Preparation of plan for improvement of facilities
[D. INSTITUTIONAL MANAGEMENT]	– Training and education	– Insufficient activities of farmers' organization	– Formulation of education and training programs to reinforce farmers' and water management organizations – Implementation of the programs	– Preparation of guidelines for the formulation – Proposal for implementation of Model Project

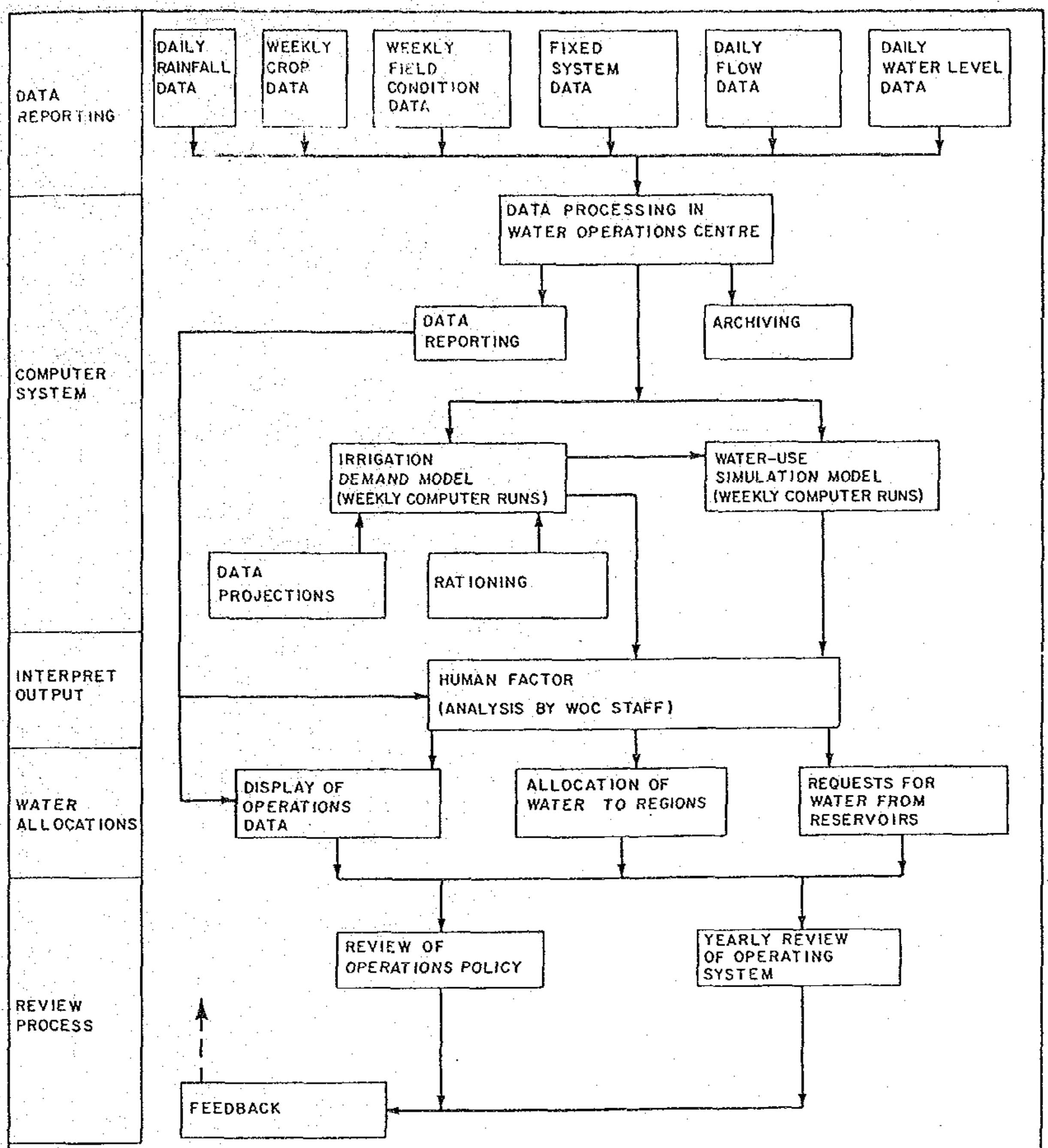


Figure 1-1 INFORMATION FLOW IN WATER OPERATION CENTER

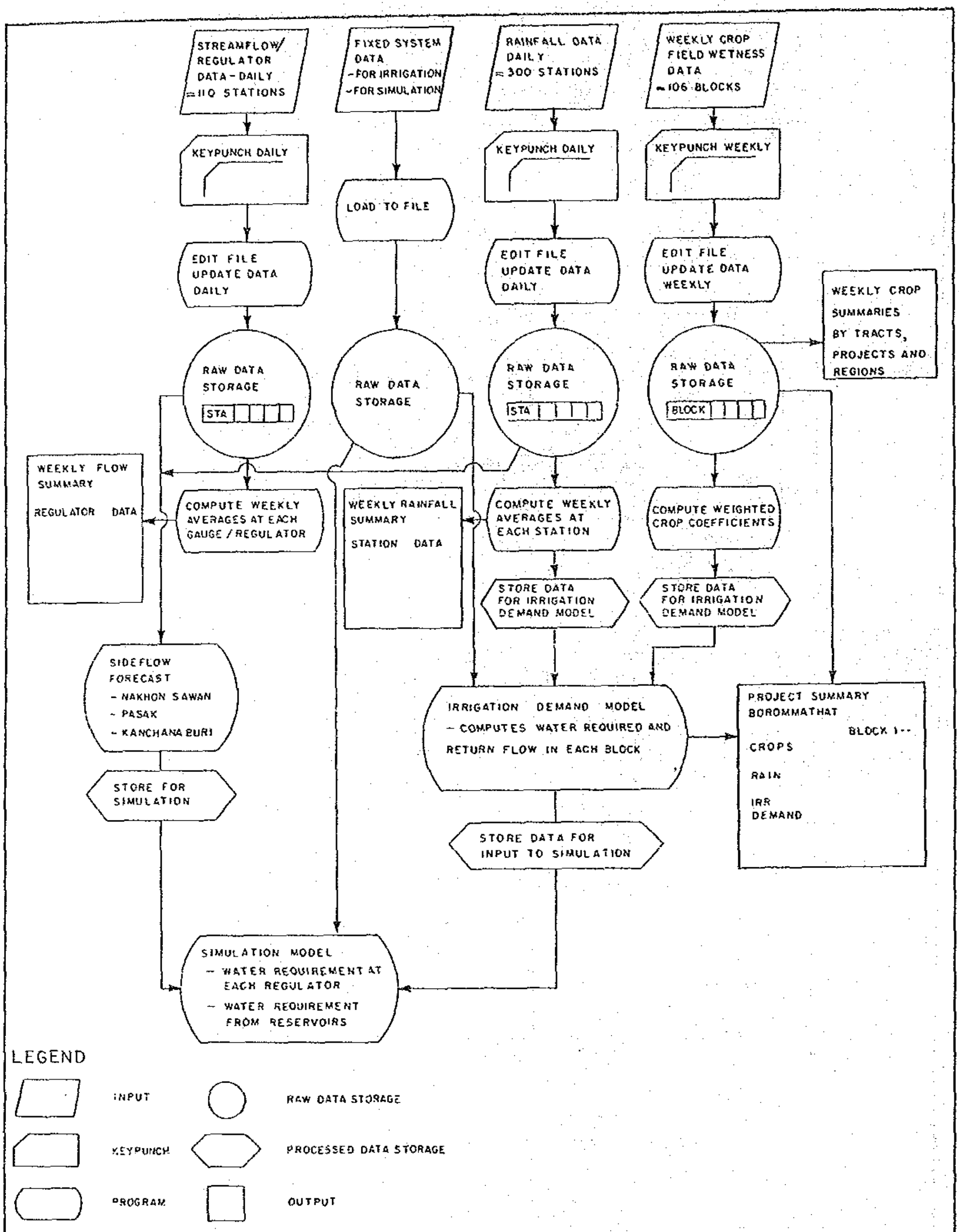


Figure 1-2 COMPUTER SYSTEM

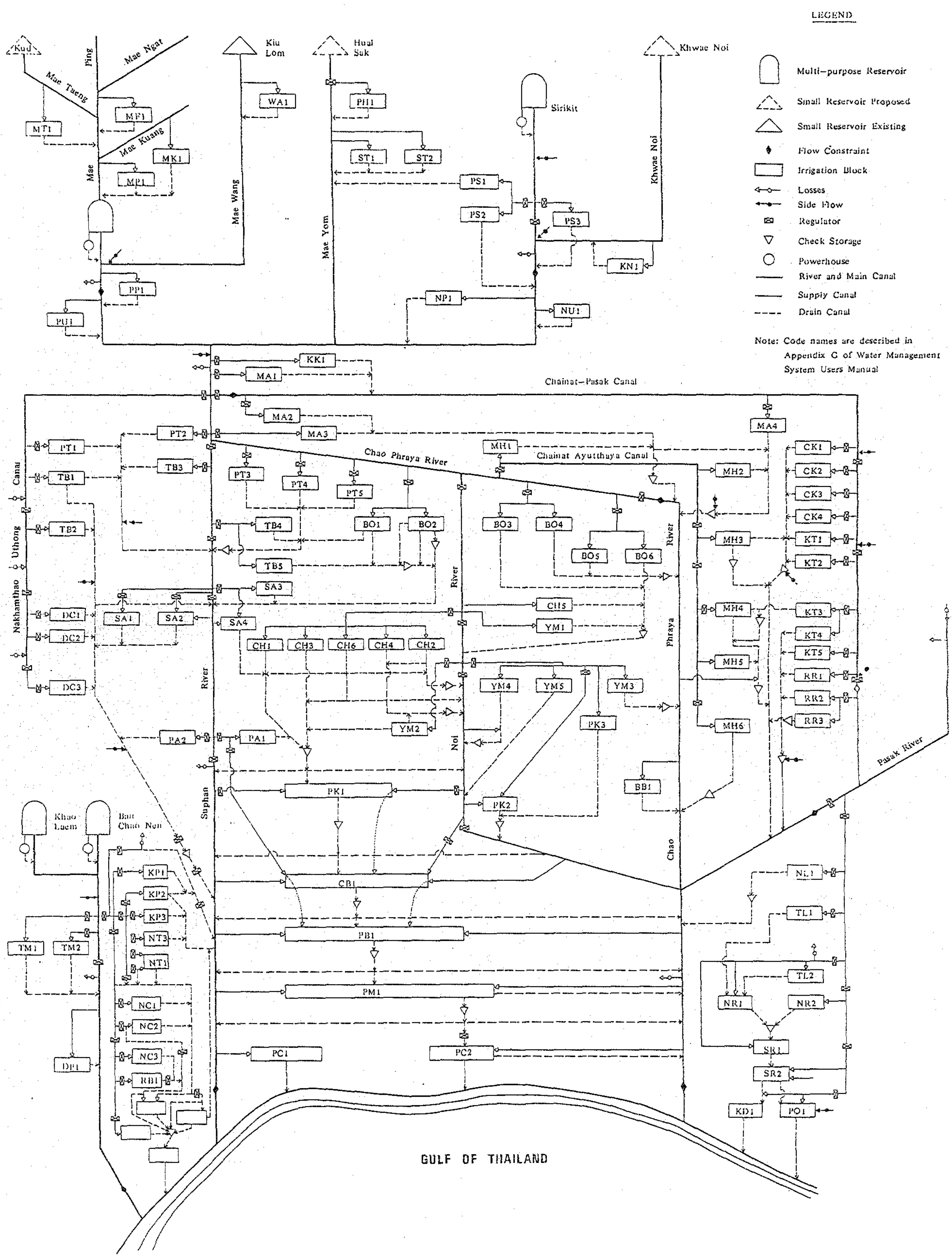


Figure 1-3 PRESENT WATER MANAGEMENT MODEL SCHEMATIC

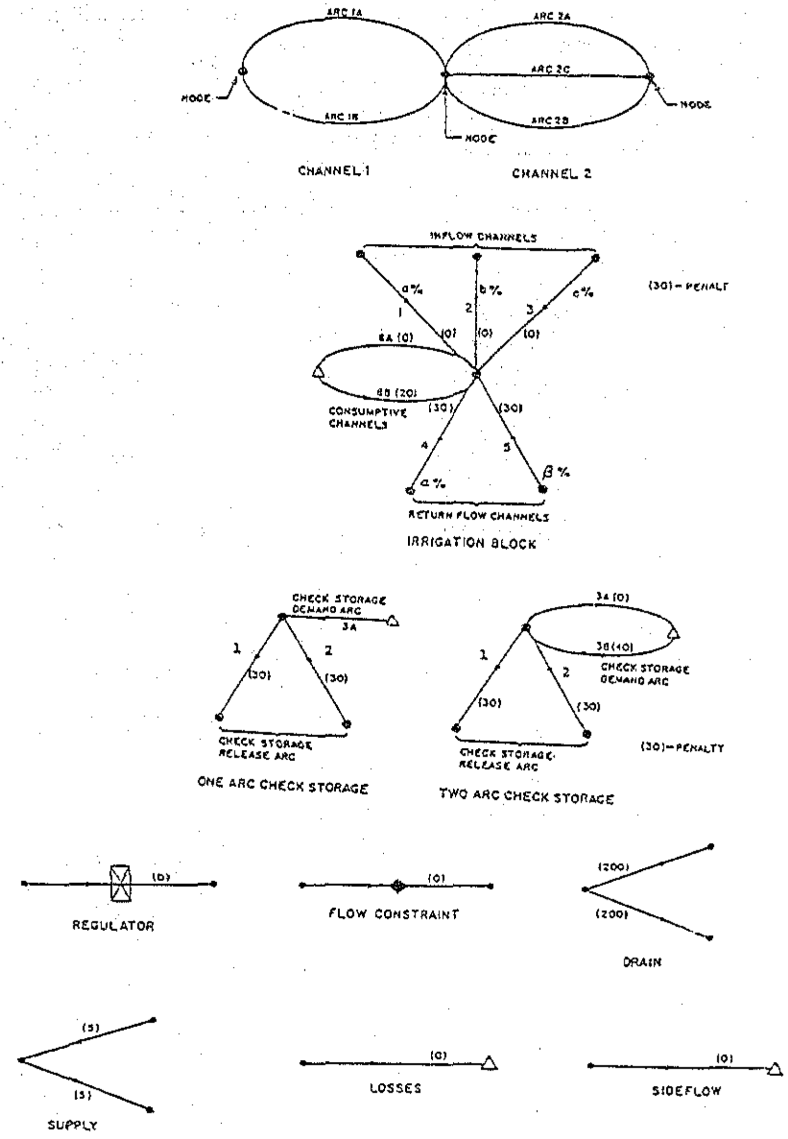


Figure 1-4 OUT OF KILTER ALGORITHM SCHEMATIC

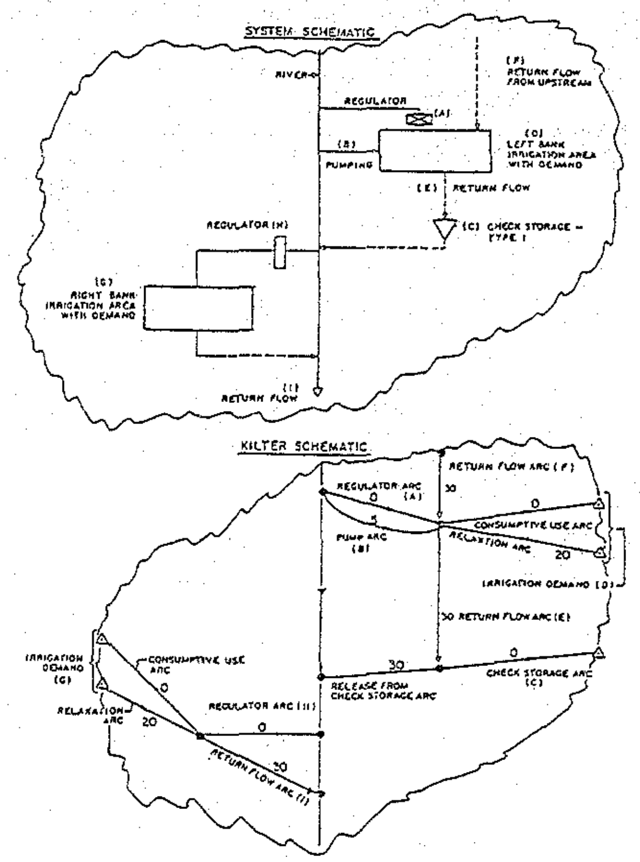


Figure 1-5 EXAMPLE SCHMATIC

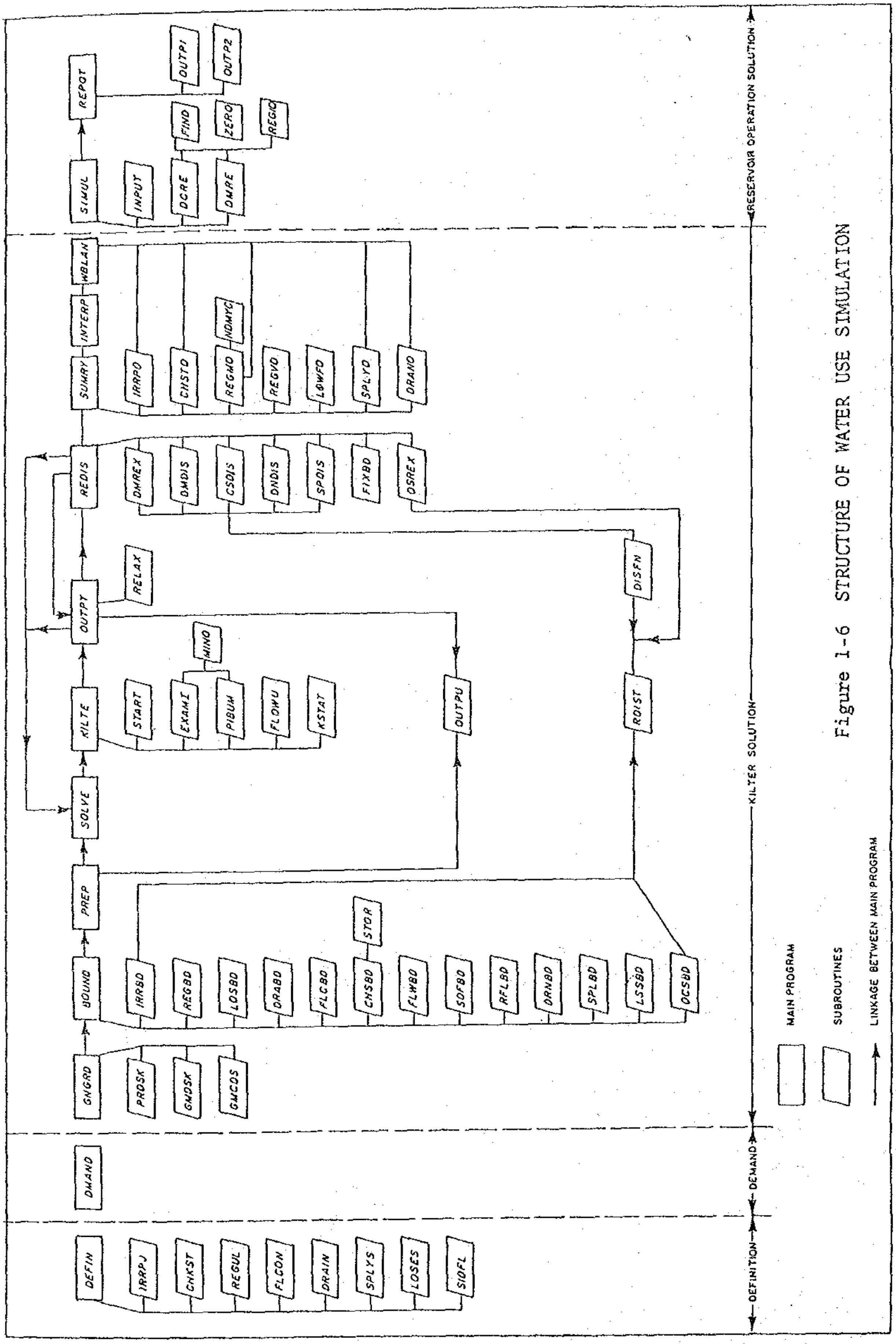


Figure 1-6 STRUCTURE OF WATER USE SIMULATION

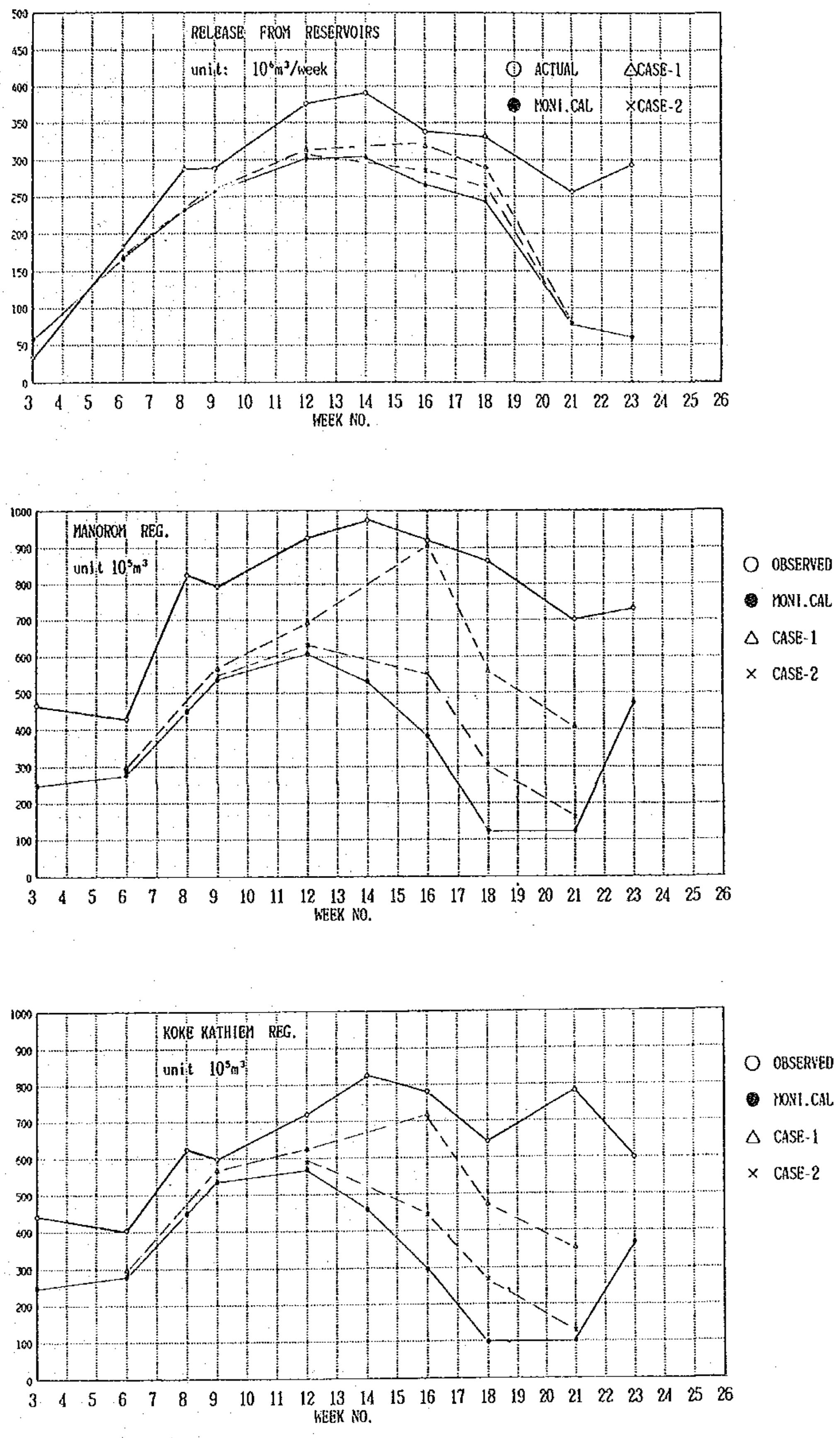


Figure 1-7 RESULTS OF MODIFICATION

Figure 1-9 DISCHARGES IN CHAINAT-PASAK CANAL

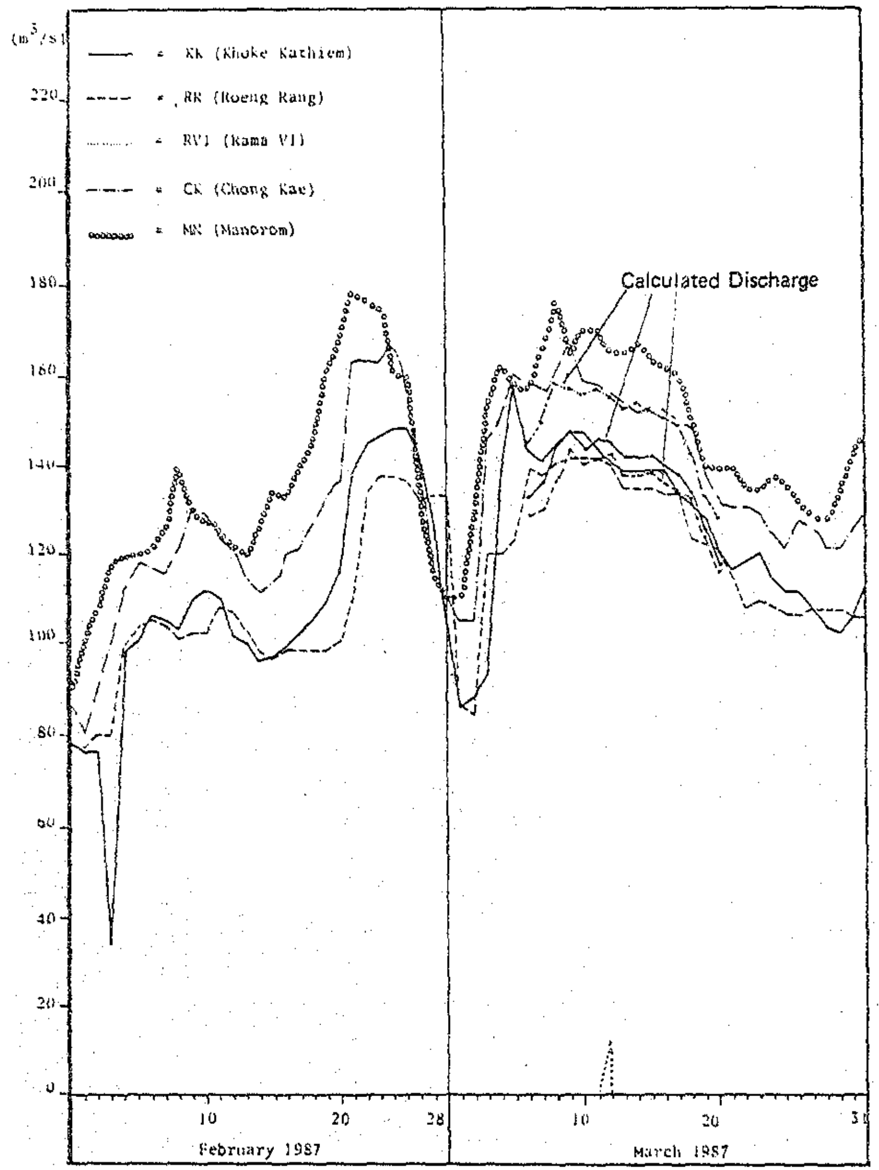
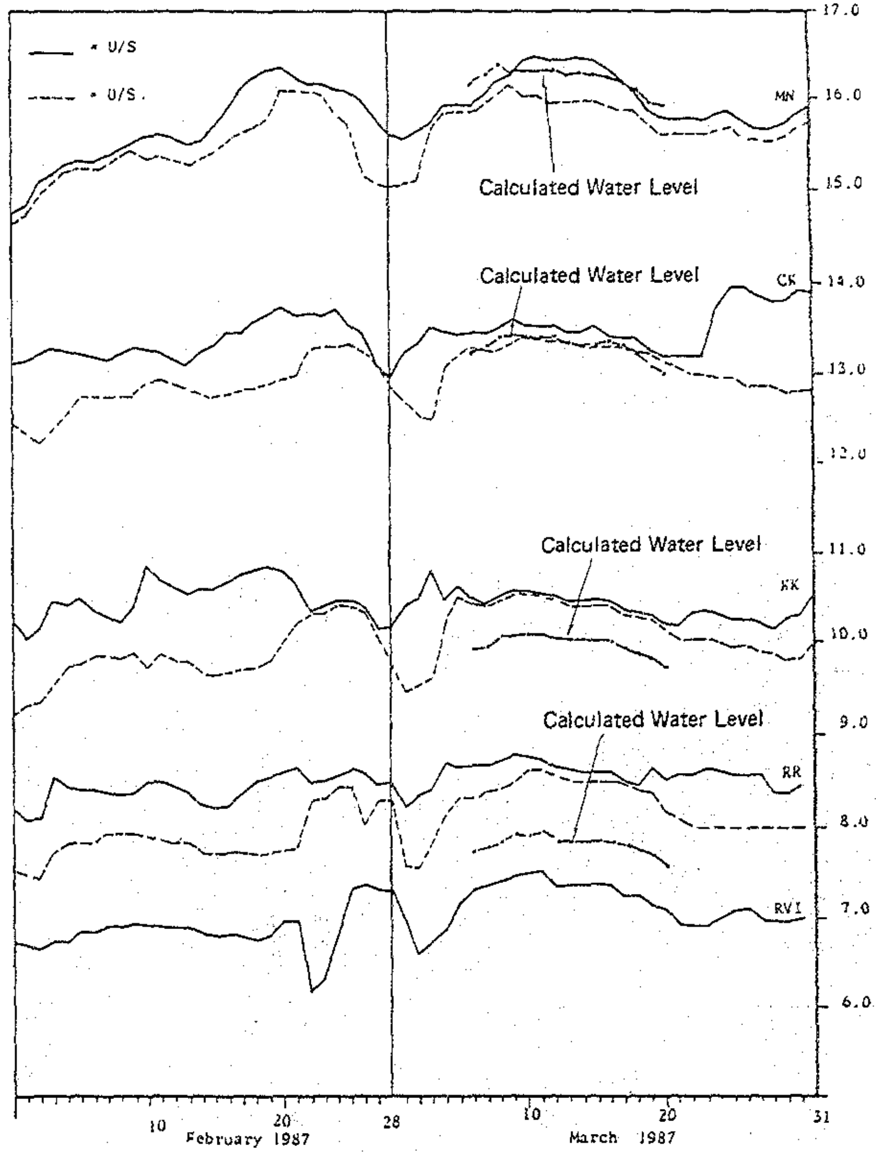


Figure 1-10 WATER LEVELS IN CHAINAT-PASAK CANAL



Monthly Rainfall by sub-basin

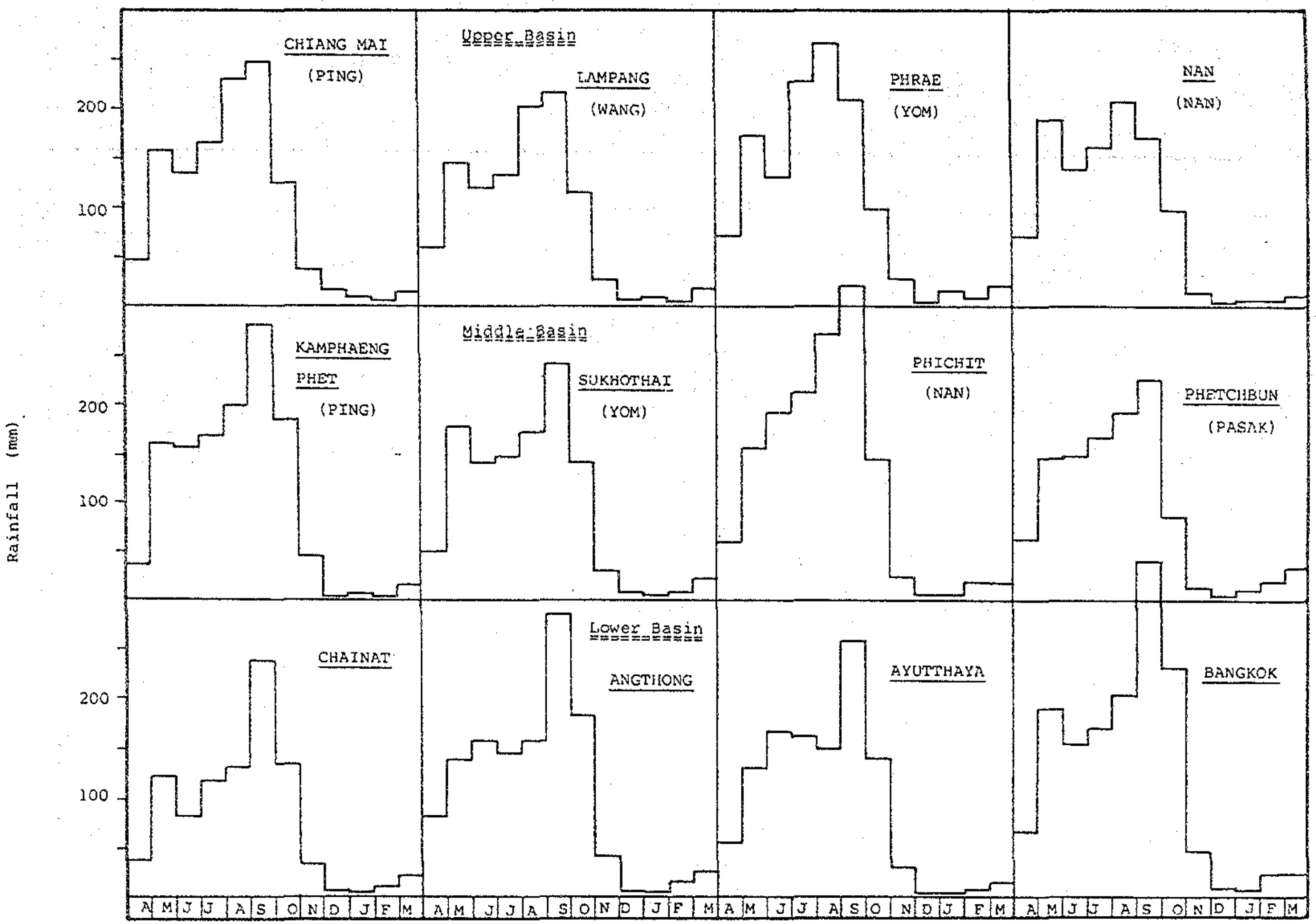


Figure 2-1 MONTHLY RAINFALL BY SUB-BASIN

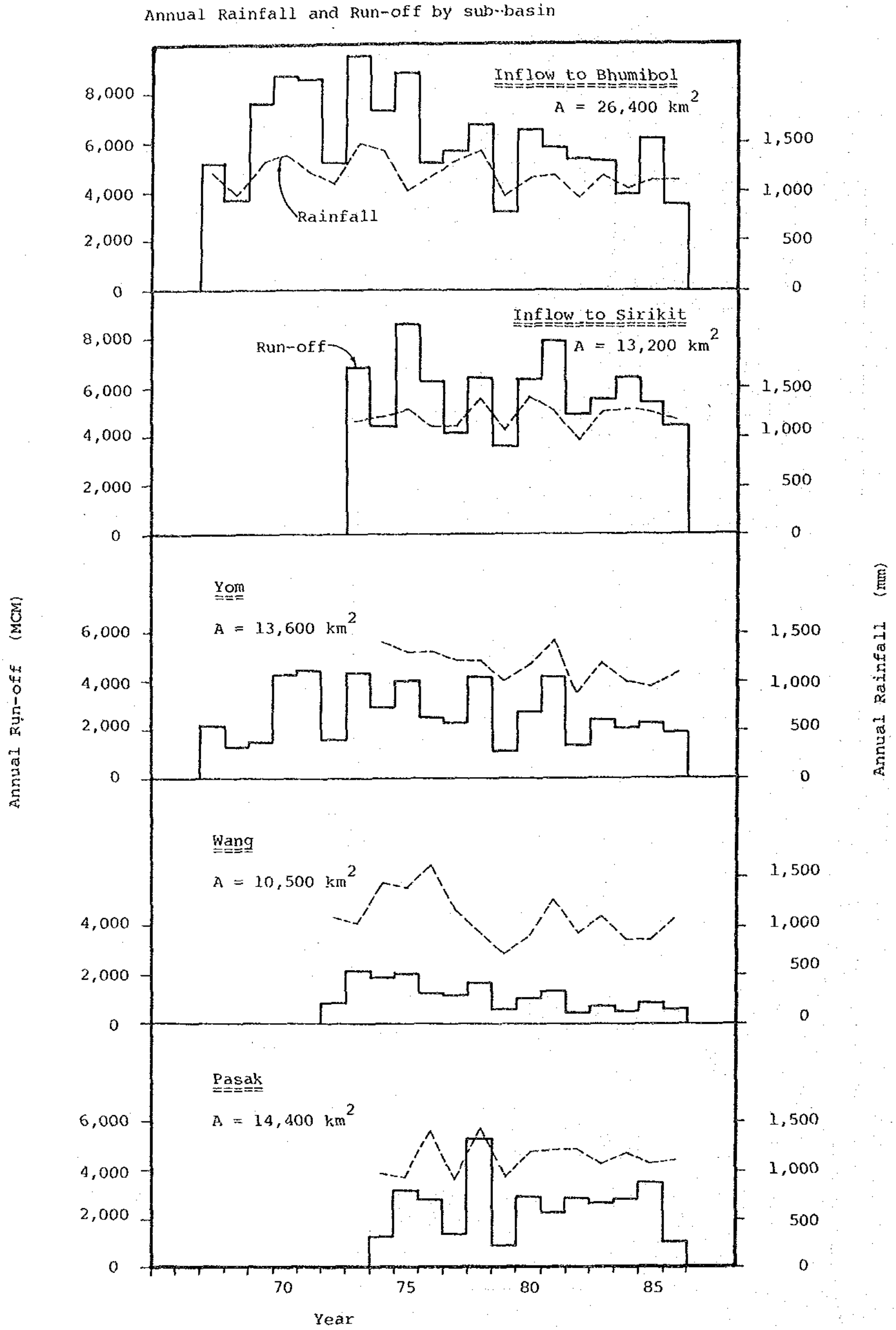
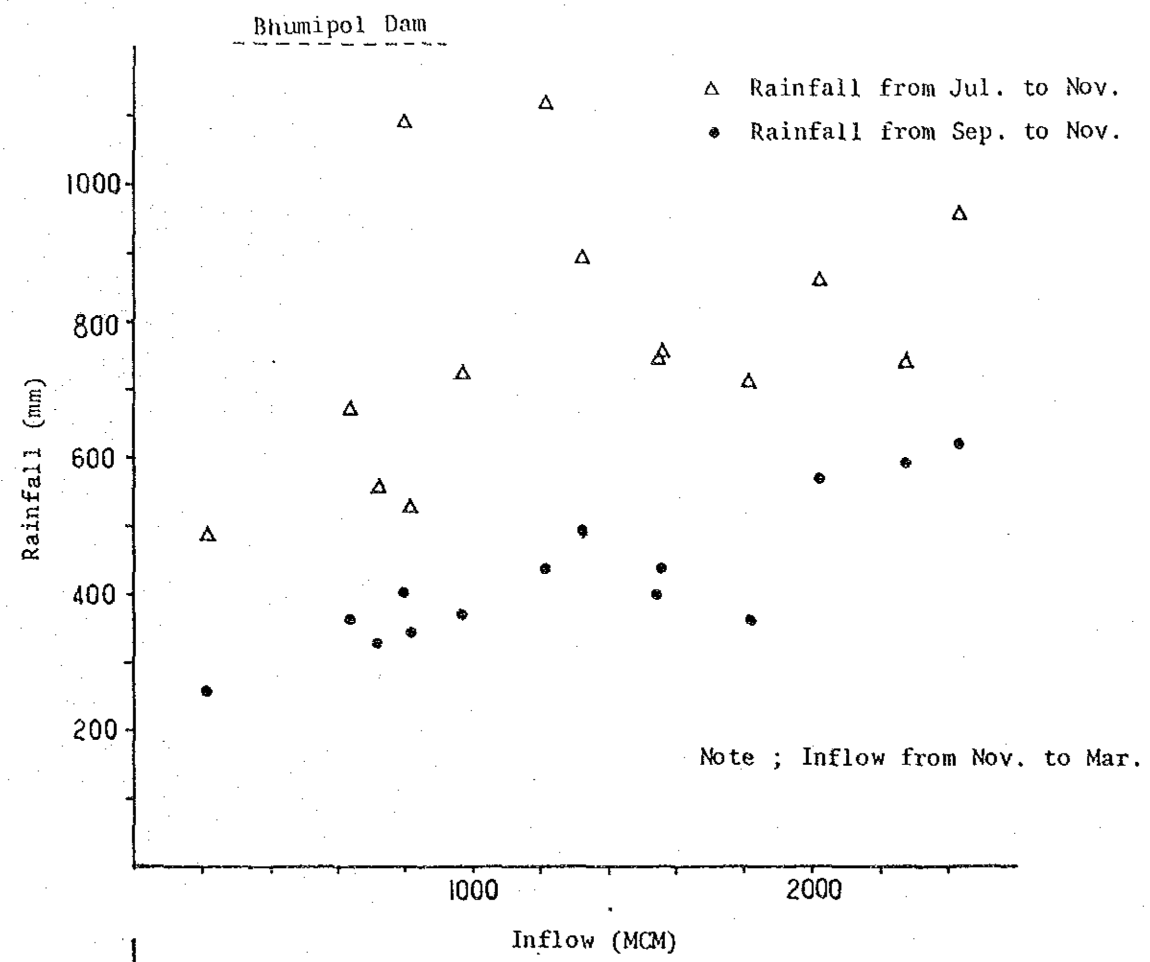


Figure 2-2 ANNUAL RAINFALL AND RUN-OFF BY SUB-BASIN



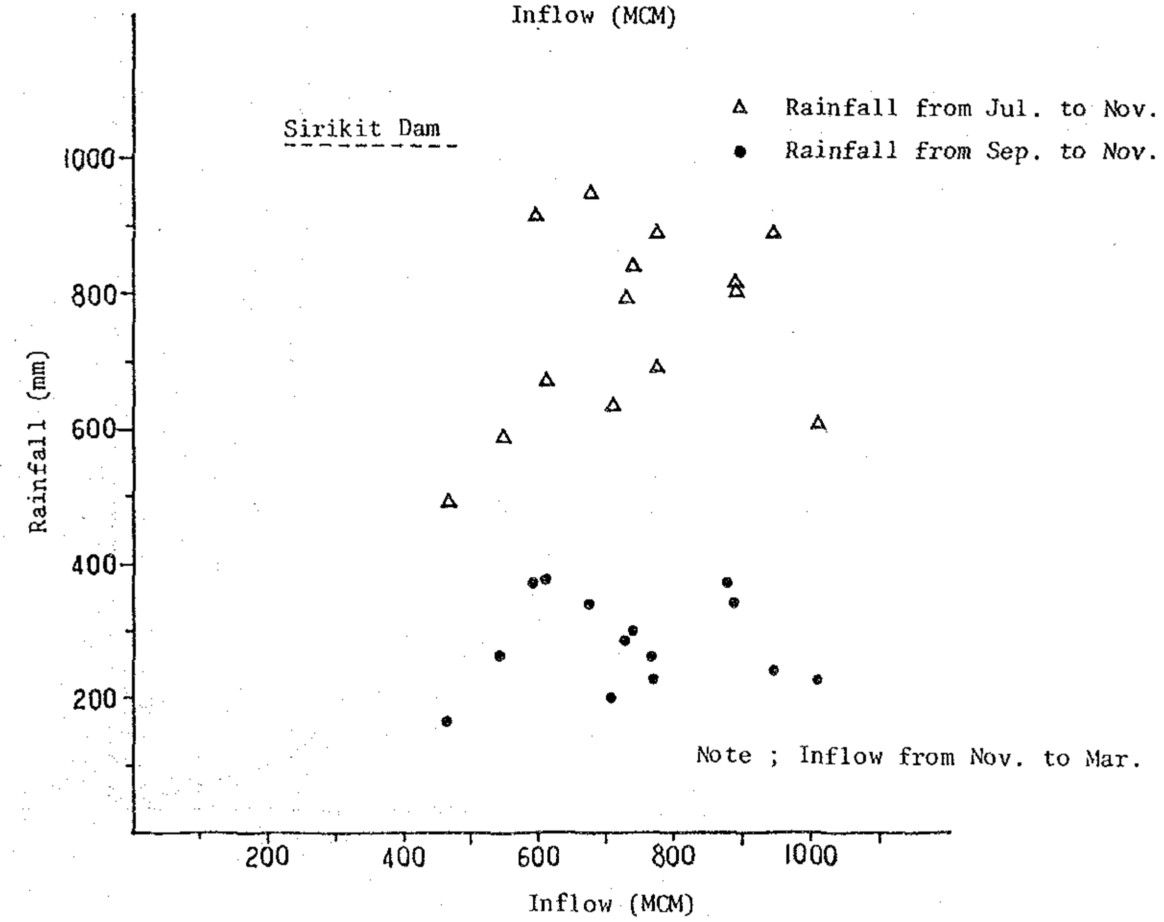


Figure 2-3 RELATION BETWEEN RAINFALL AND RESERVOIR INFLOW

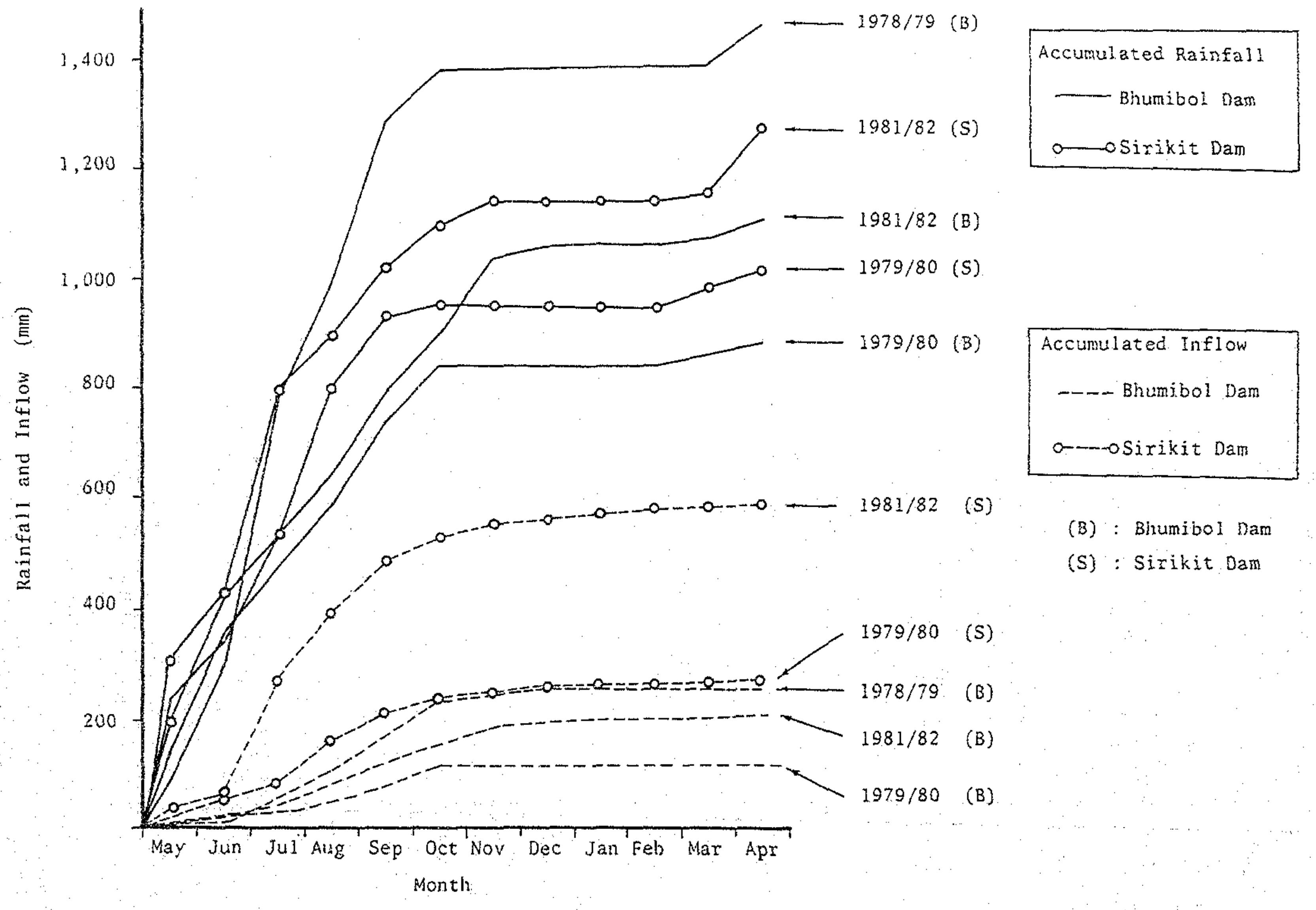


Figure 2-4 RELATION BETWEEN ACCUMULATED RAINFALL AND INFLOW

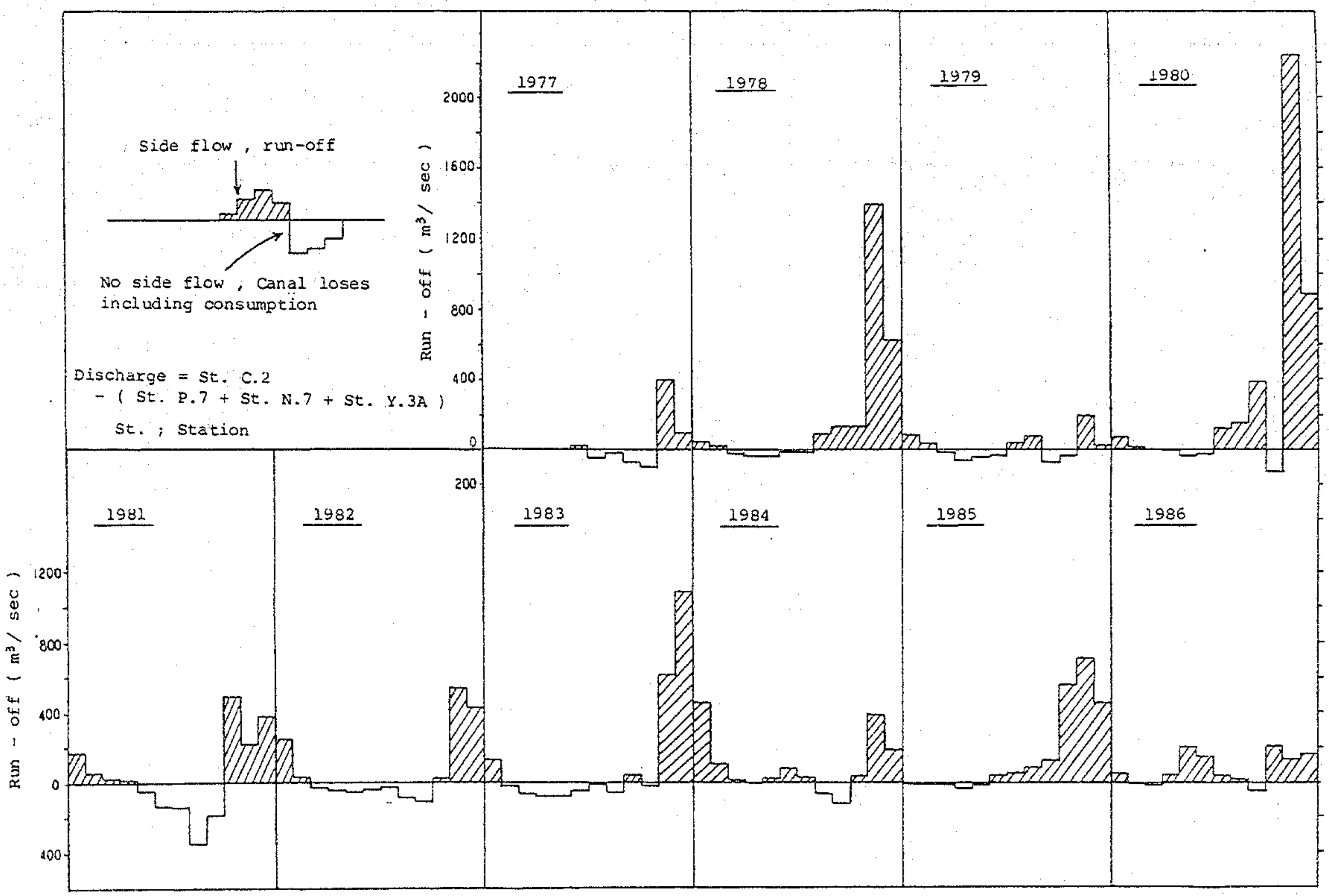


Figure 2-5 MONTHLY SIDEFLOW BETWEEN BOTH DAMS AND NAKHON SAWAN

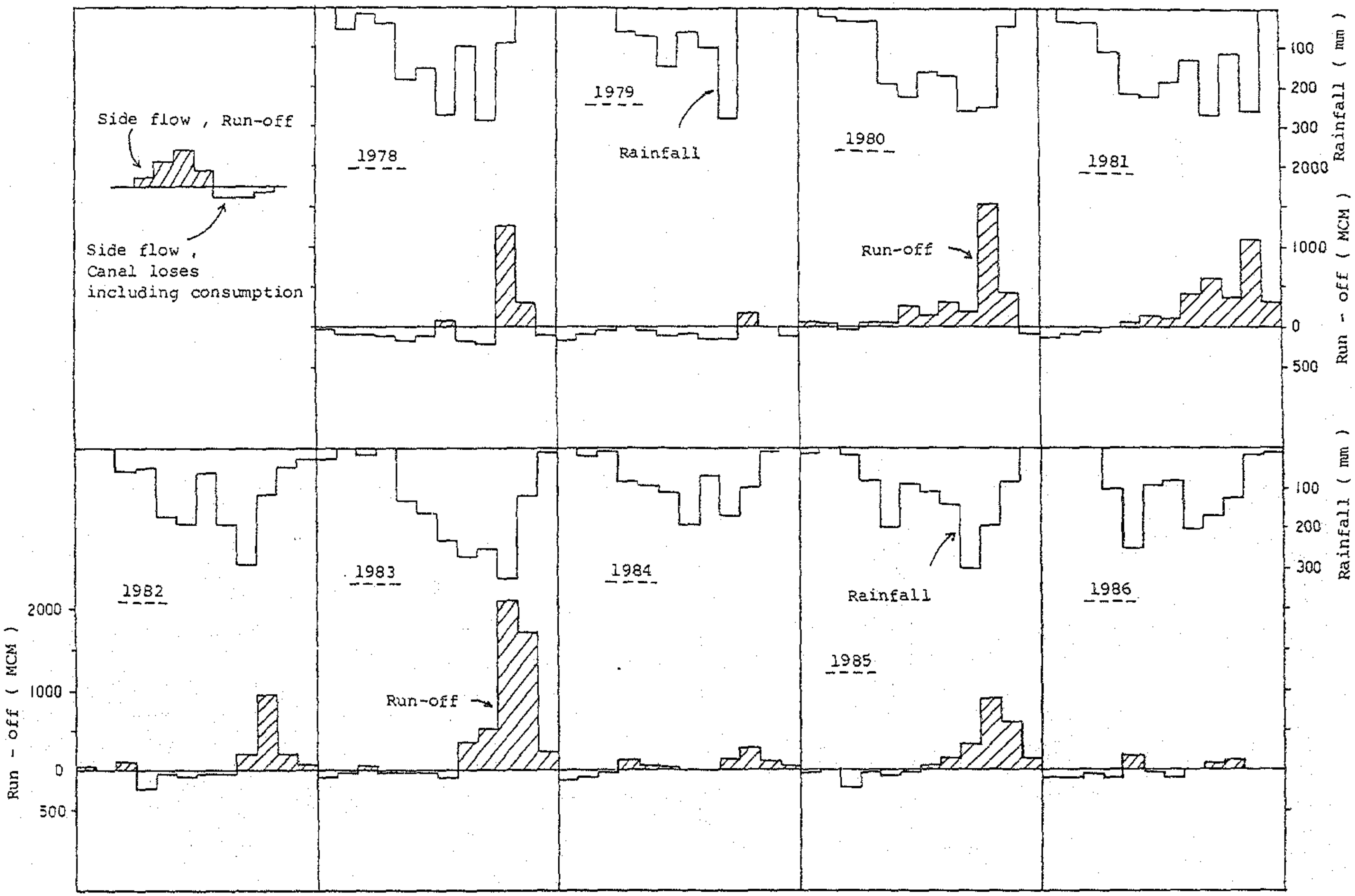


Figure 2-6 MONTHLY SIDEFLOW BETWEEN NAKHON SAWAN AND CHAINAT

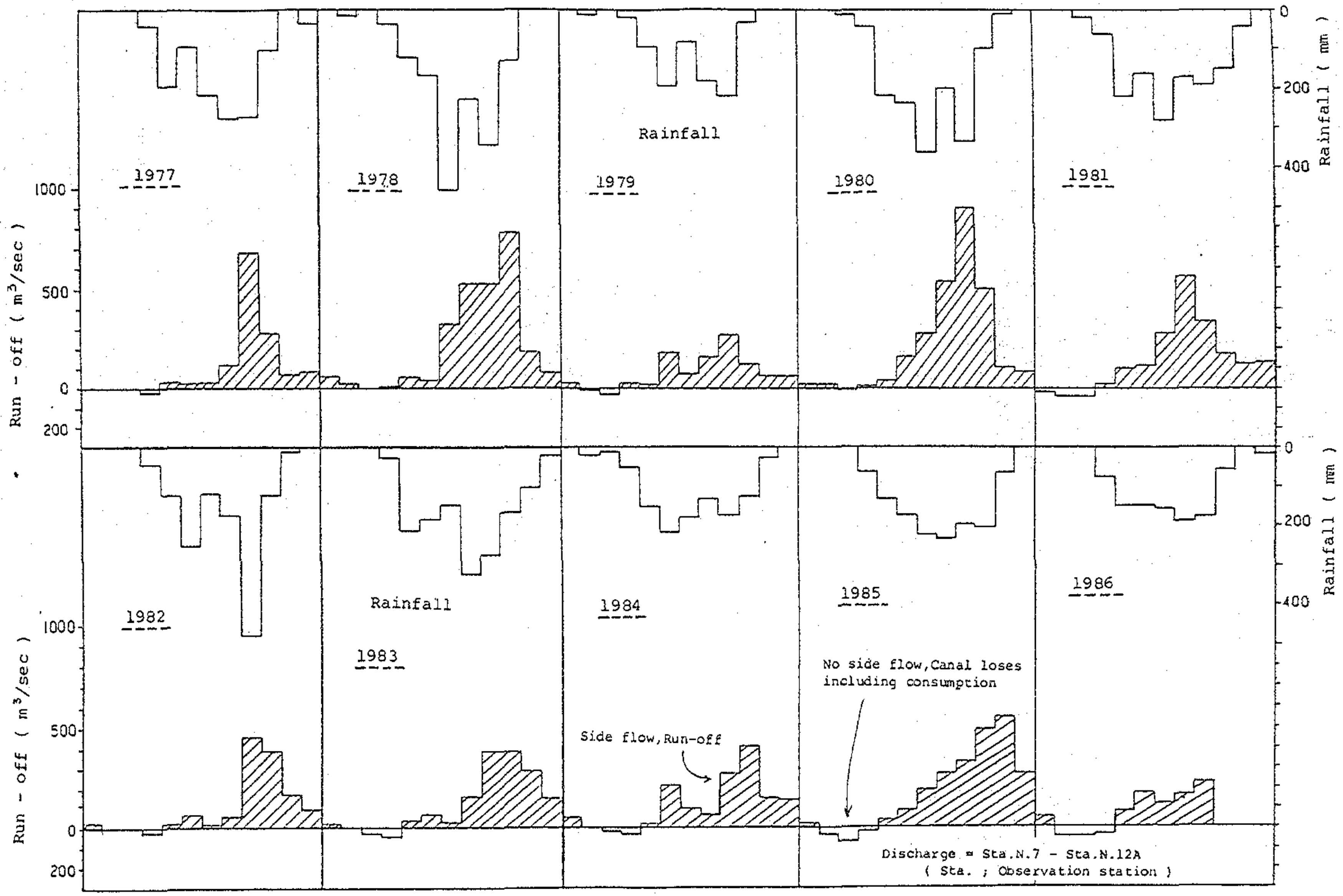


Figure 2-7 MONTHLY SIDEFLOW AND RAINFALL IN NAN RIVER

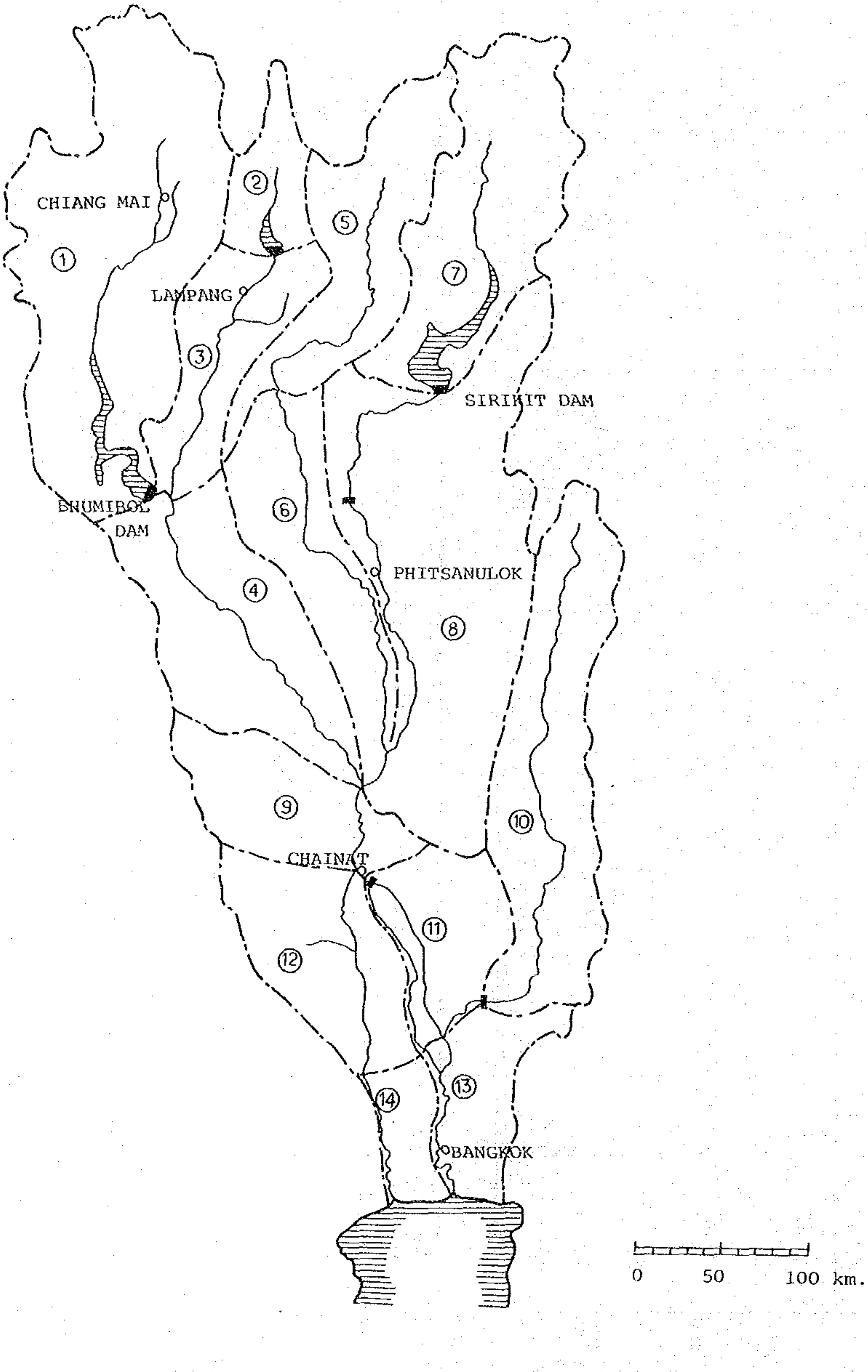


Figure 2-8 SCHEME OF SUB-BASIN IN CHAO PHRAYA BASIN

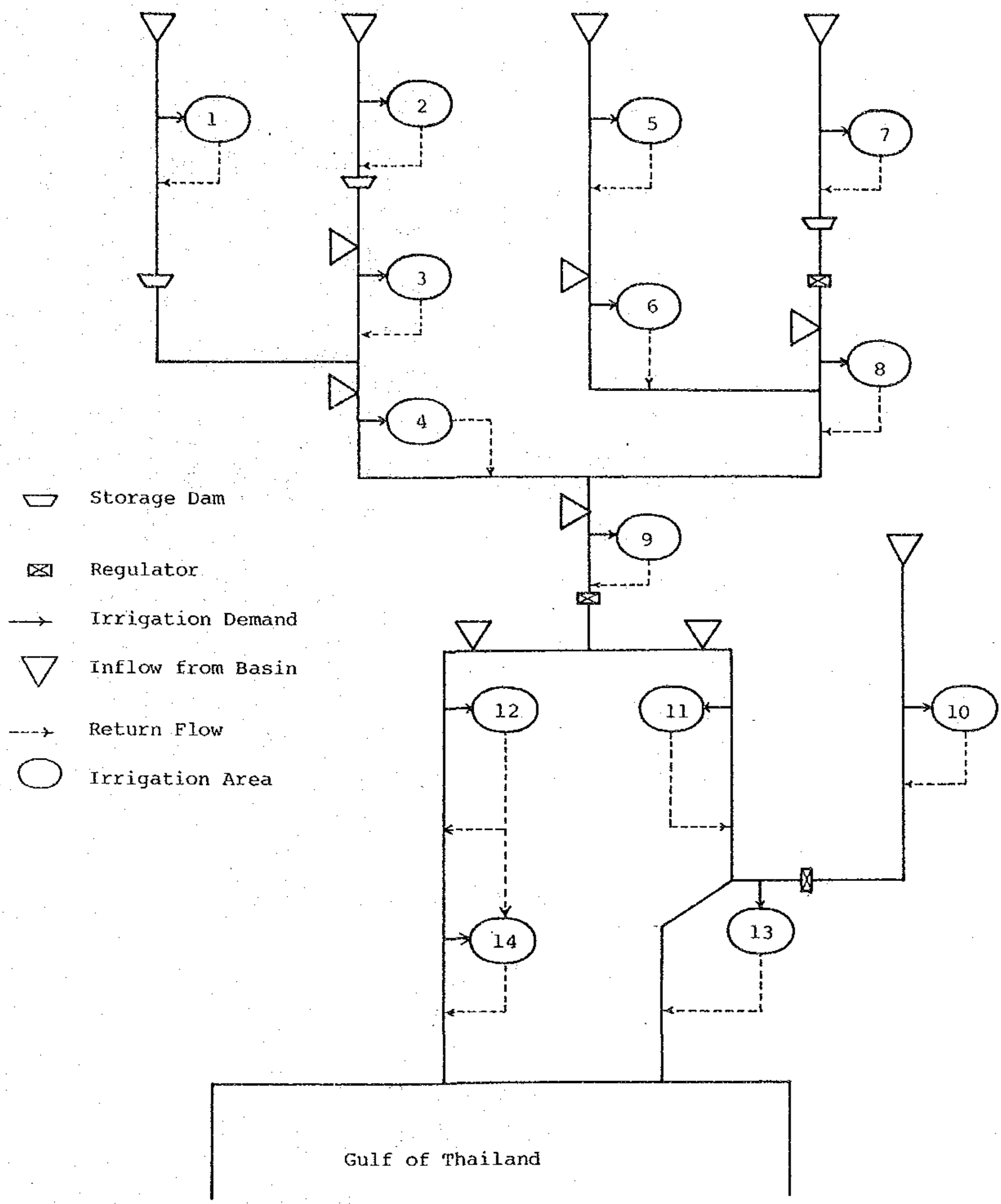


Figure 2-9 SCHEMATIC DIAGRAM OF SIMULATION MODEL

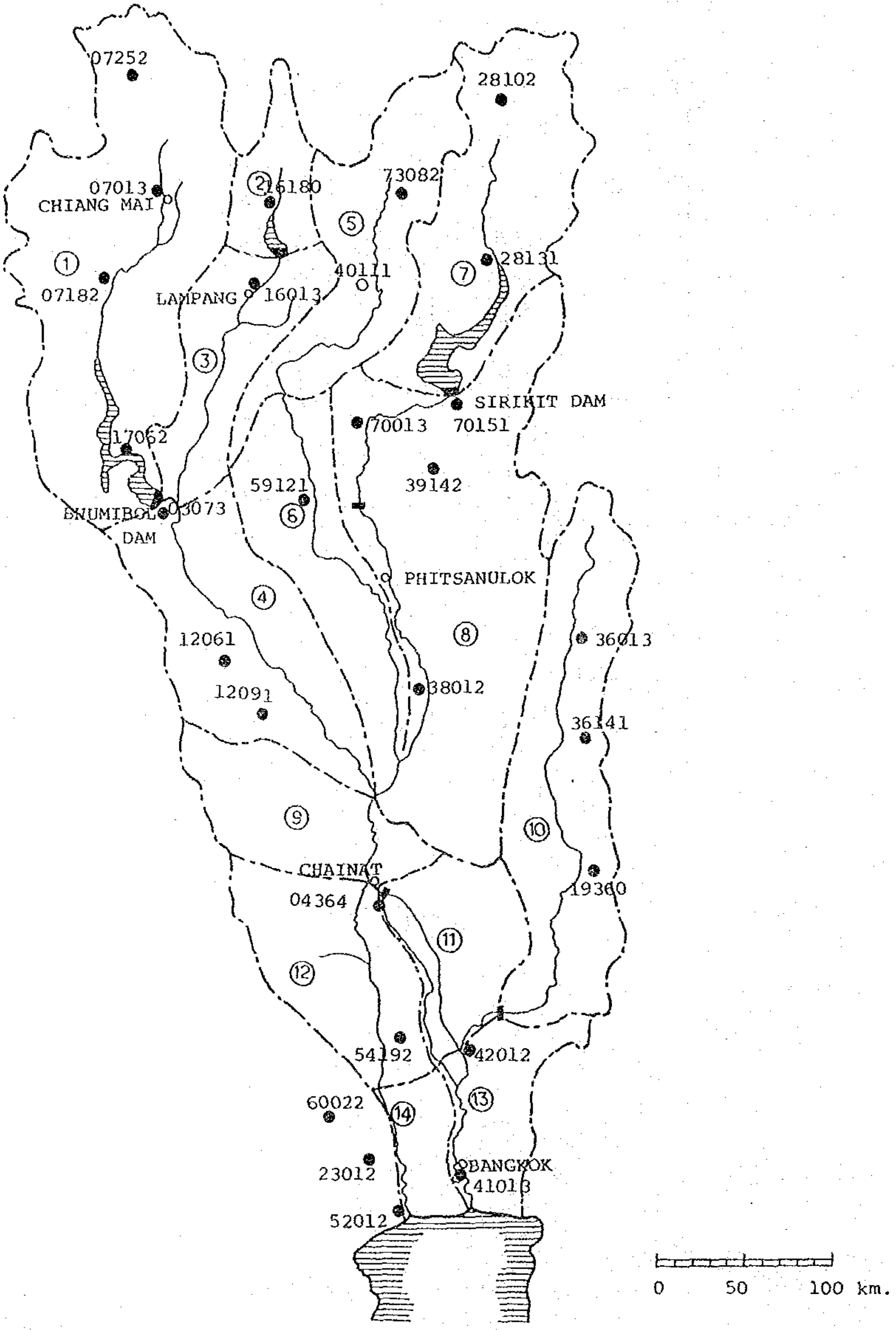


Figure 2-10 LOCATION OF RAINFALL STATION

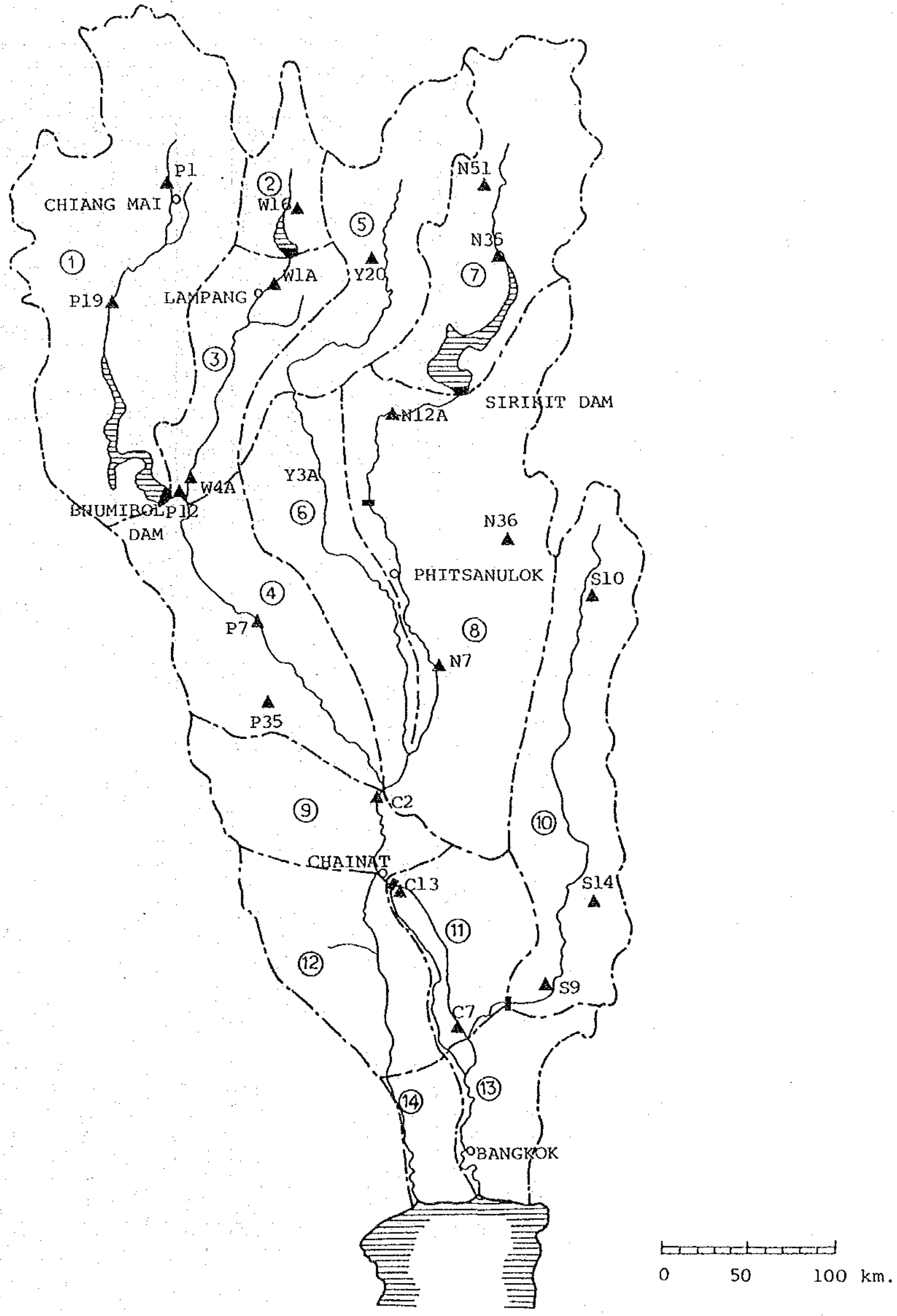


Figure 2-11 LOCATION OF RUN-OFF OBSERVATION STATION

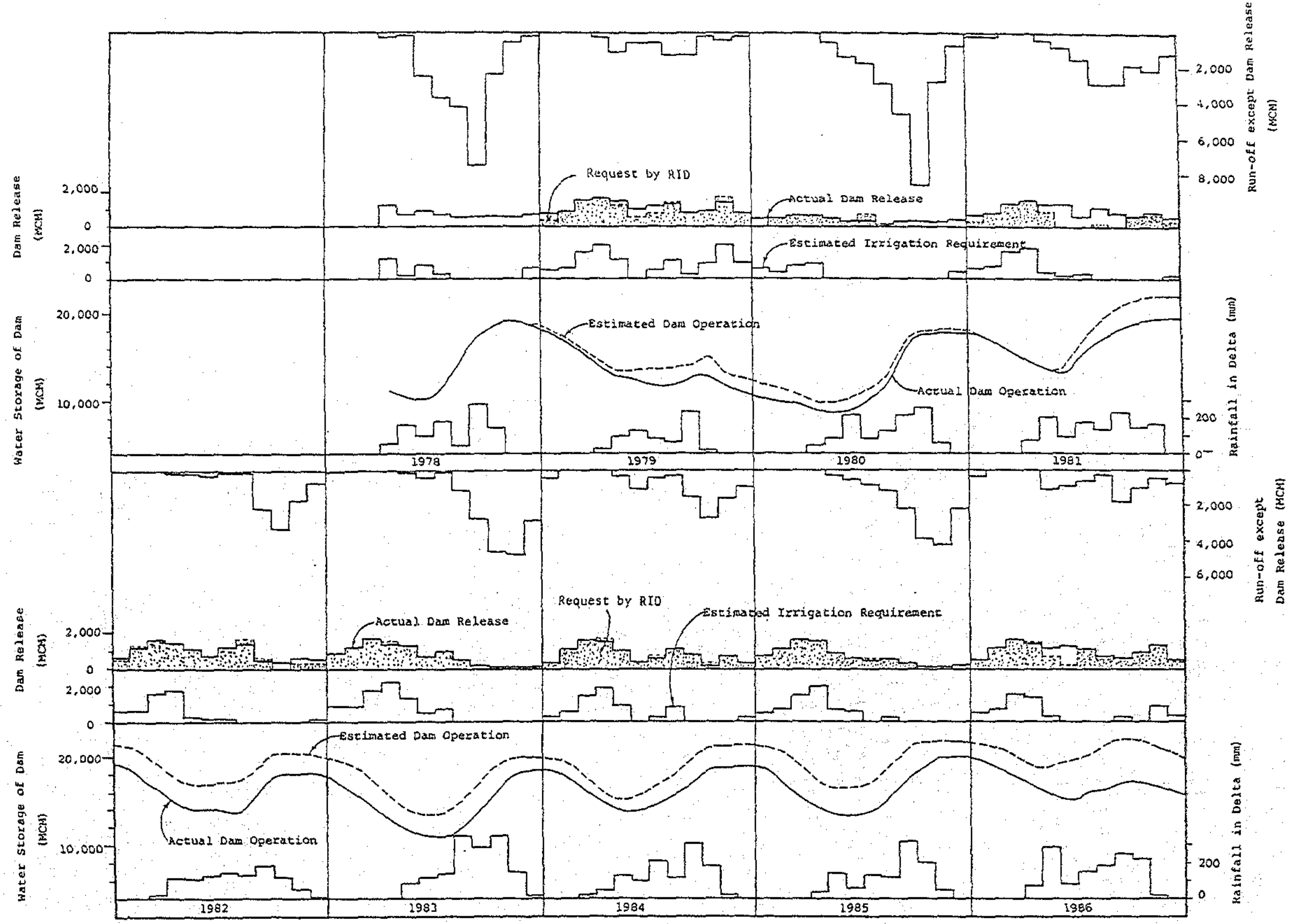


Figure 2-12 EXAMINATION OF PAST DAM OPERATION AND SIDEFLOW

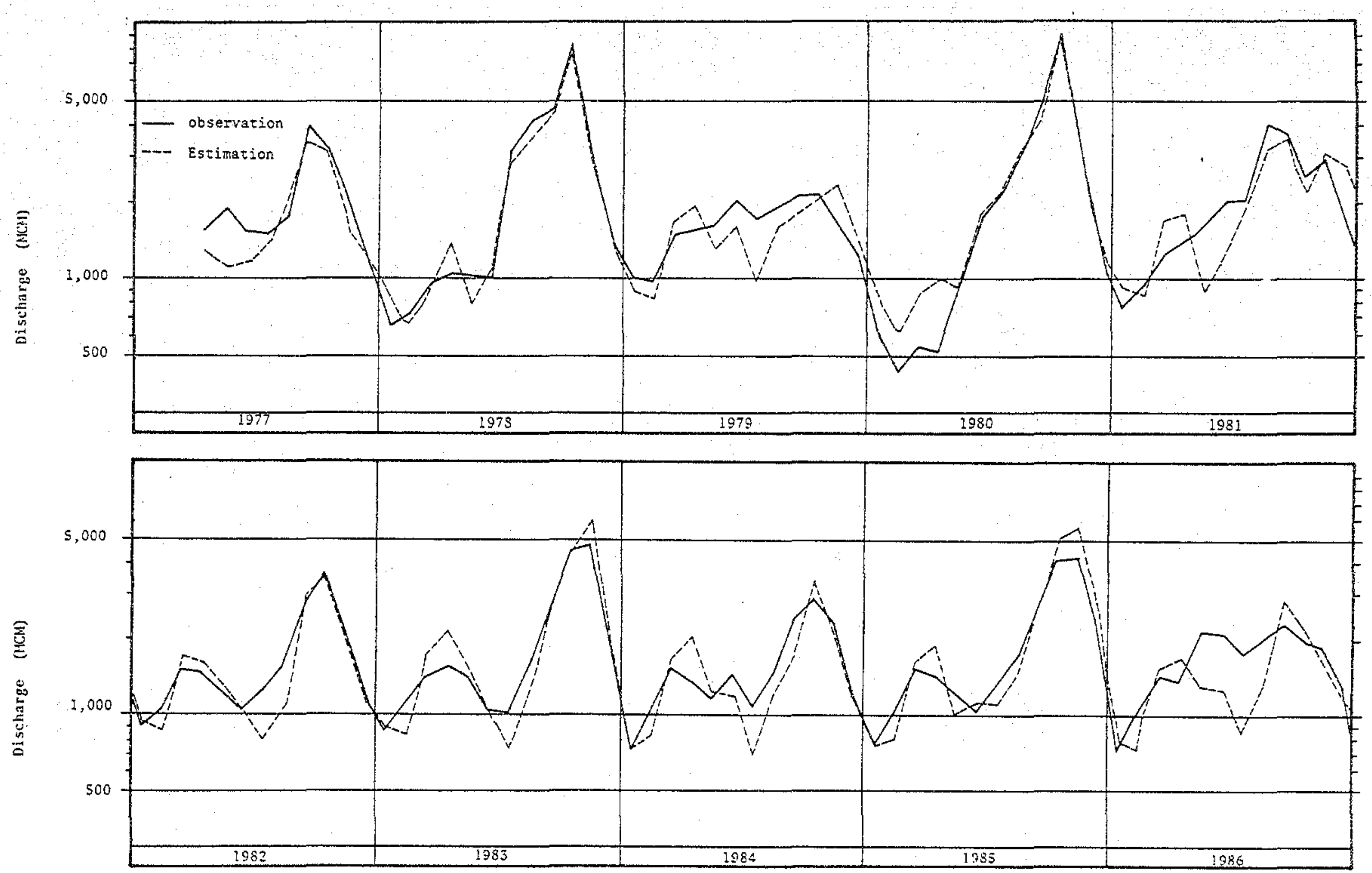


Figure 2-13 COMPARISON OF MONTHLY WATER DISCHARGE AT NAKHON SAWAN

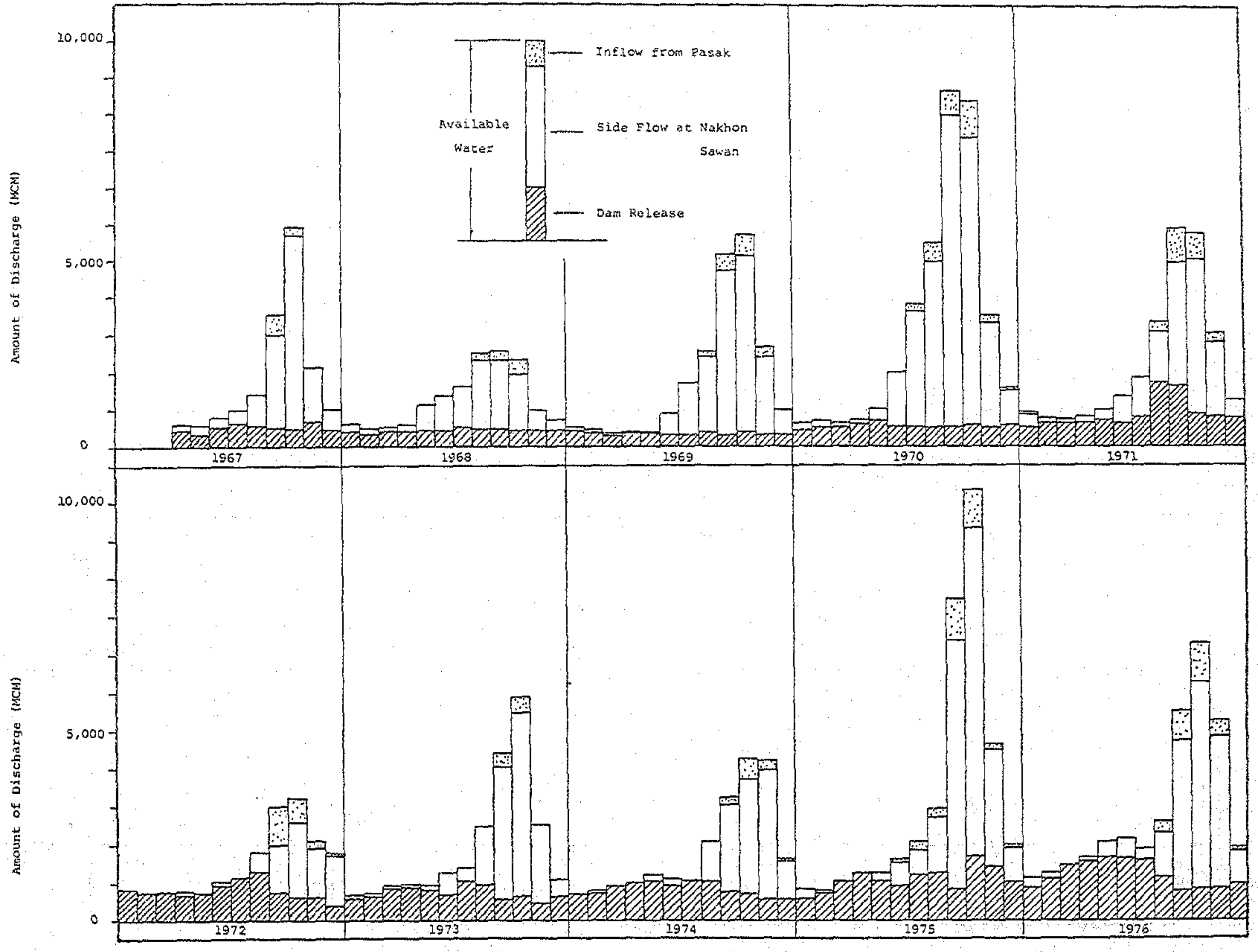


Figure 2-14 MONTHLY AVAILABLE WATER IN DELTA (1)

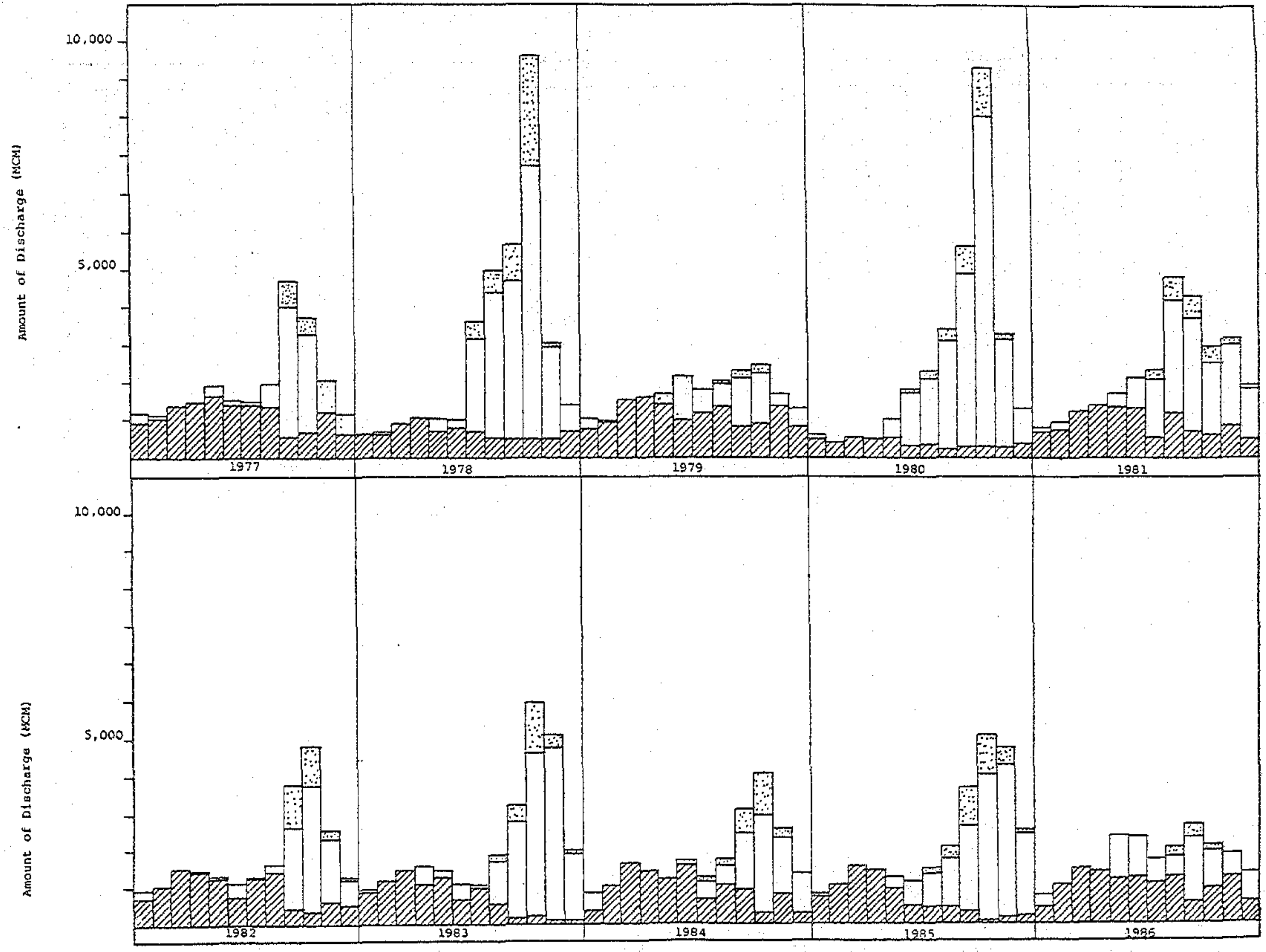


Figure 2-14 MONTHLY AVAILABLE WATER IN DELTA (2)

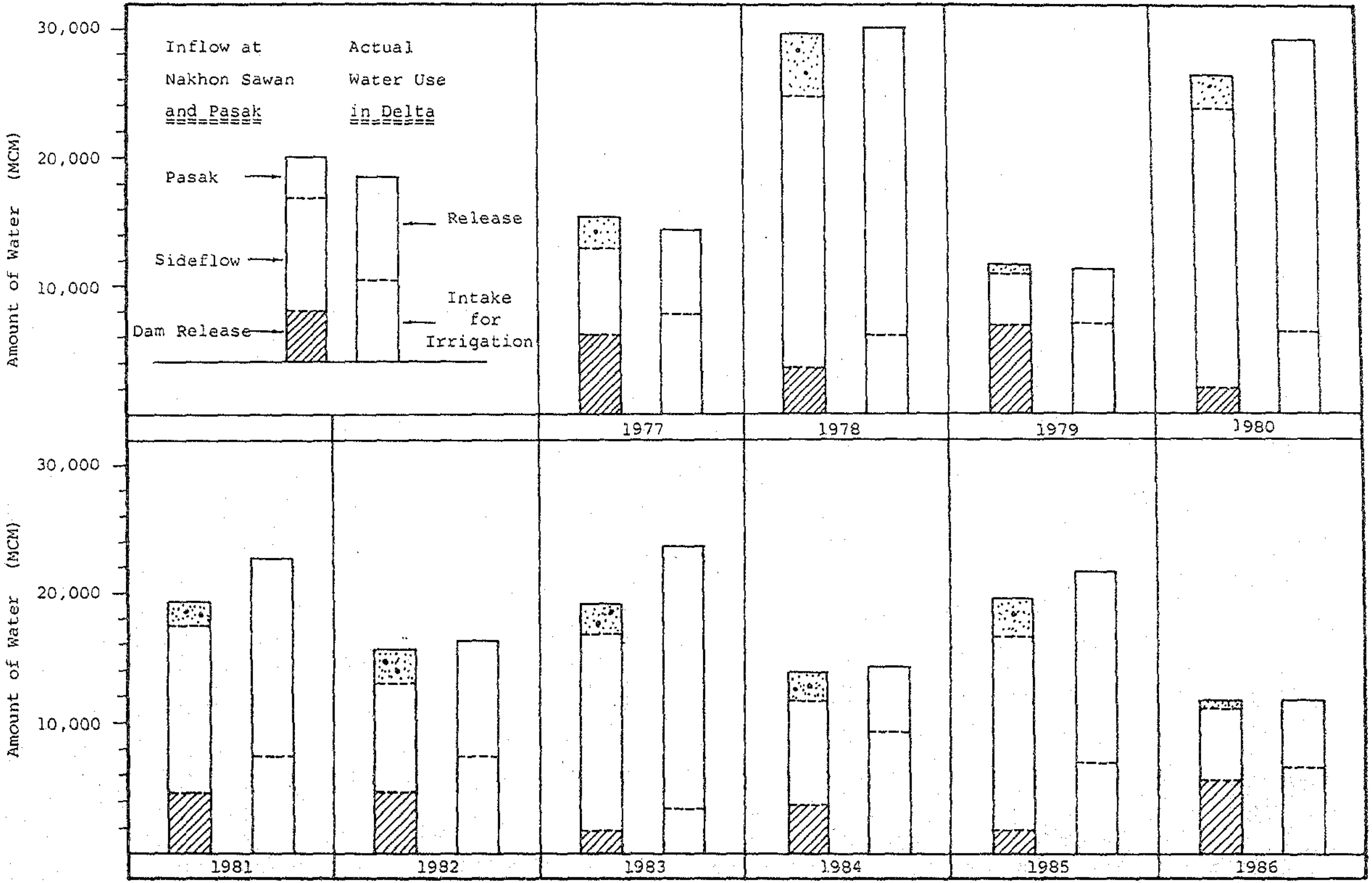


Figure 2-15 AVAILABLE WATER AND ACTUAL WATER USE IN WET SEASON

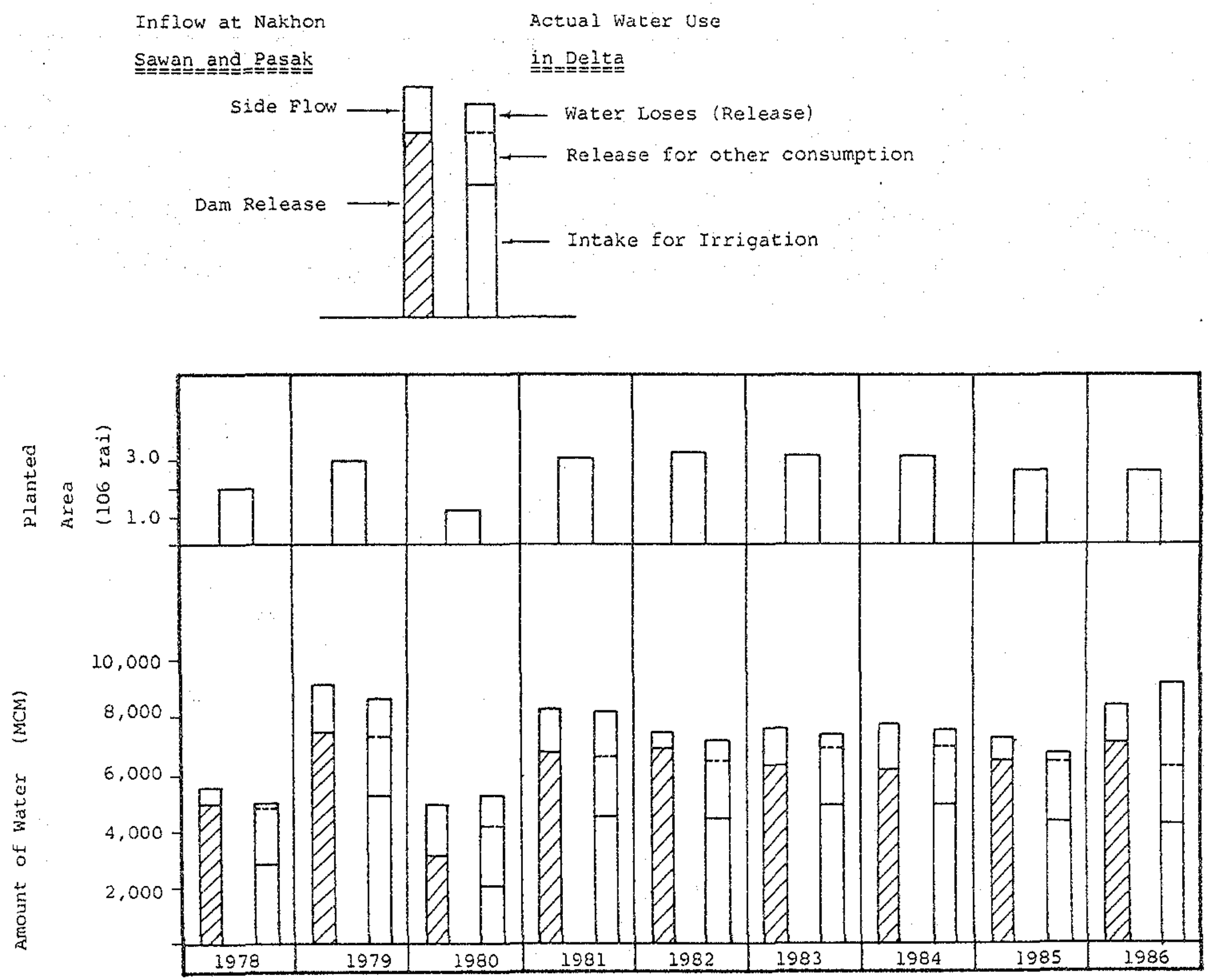


Figure 2-16 AVAILABLE WATER AND ACTUAL WATER USE IN DRY SEASON

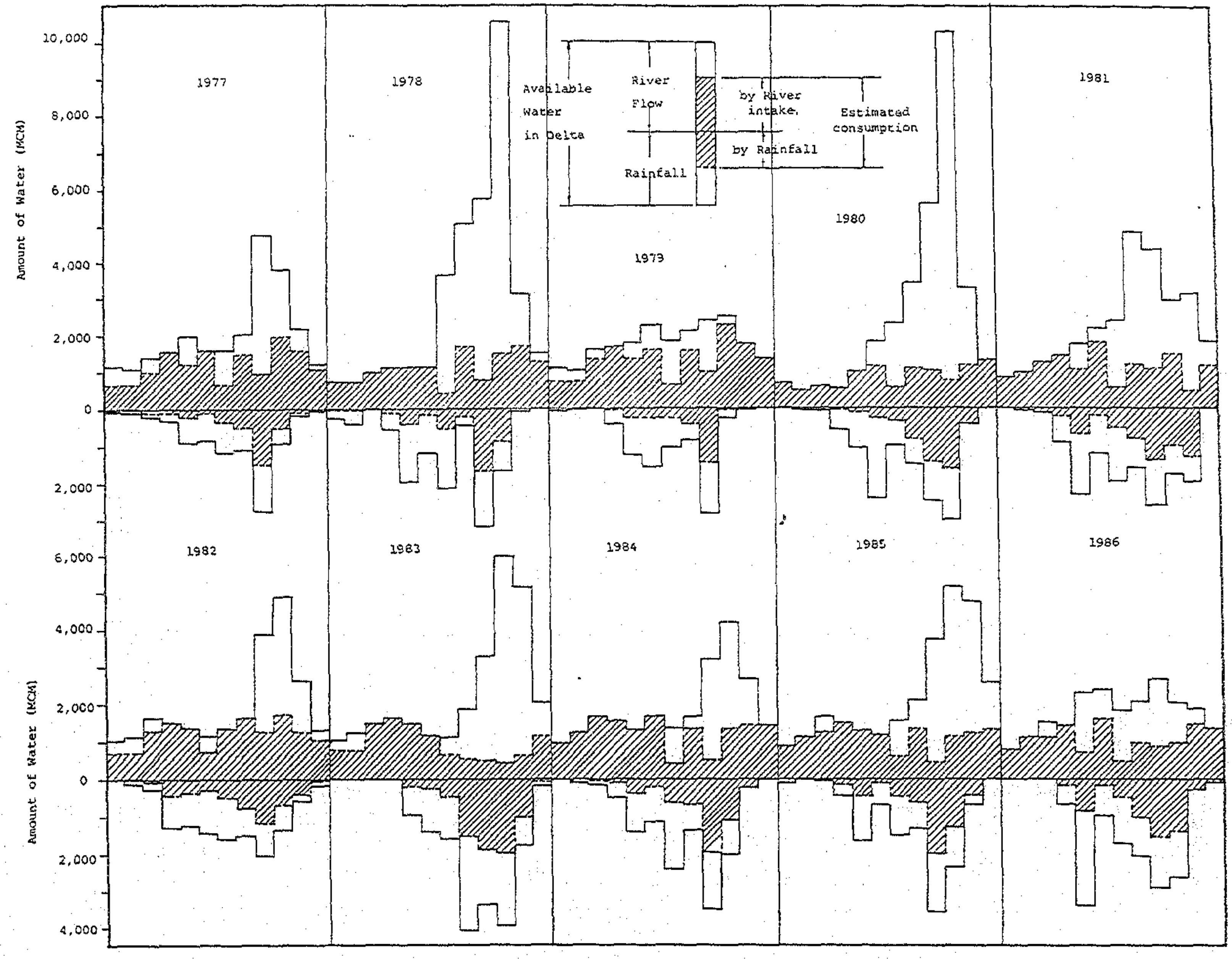


Figure 2-17 AVAILABLE WATER AND ESTIMATED CONSUMPTION IN DELTA

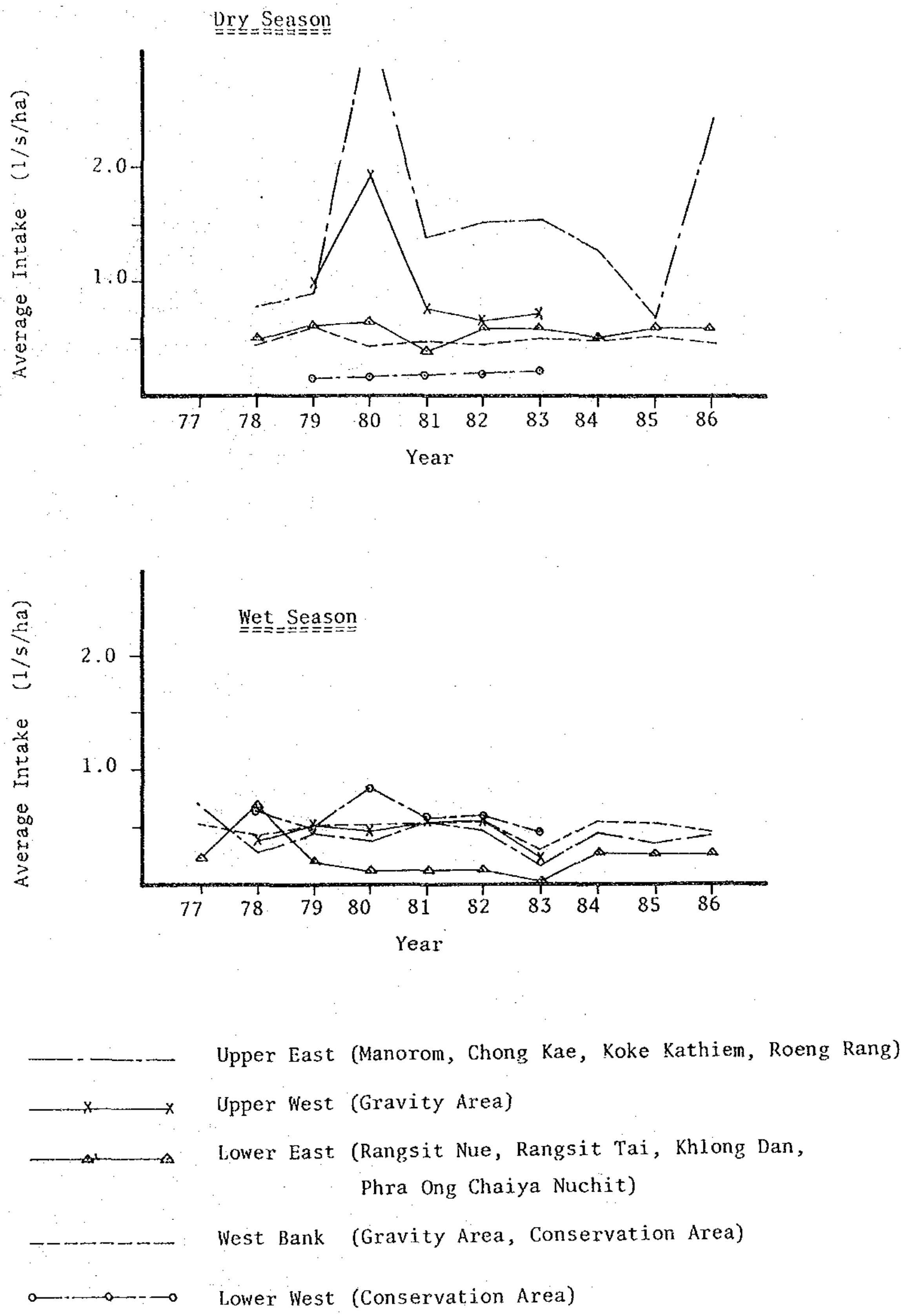


Figure 2-18 ACTUAL AVERAGE INTAKE IN DELTA

Wet Season in 1985

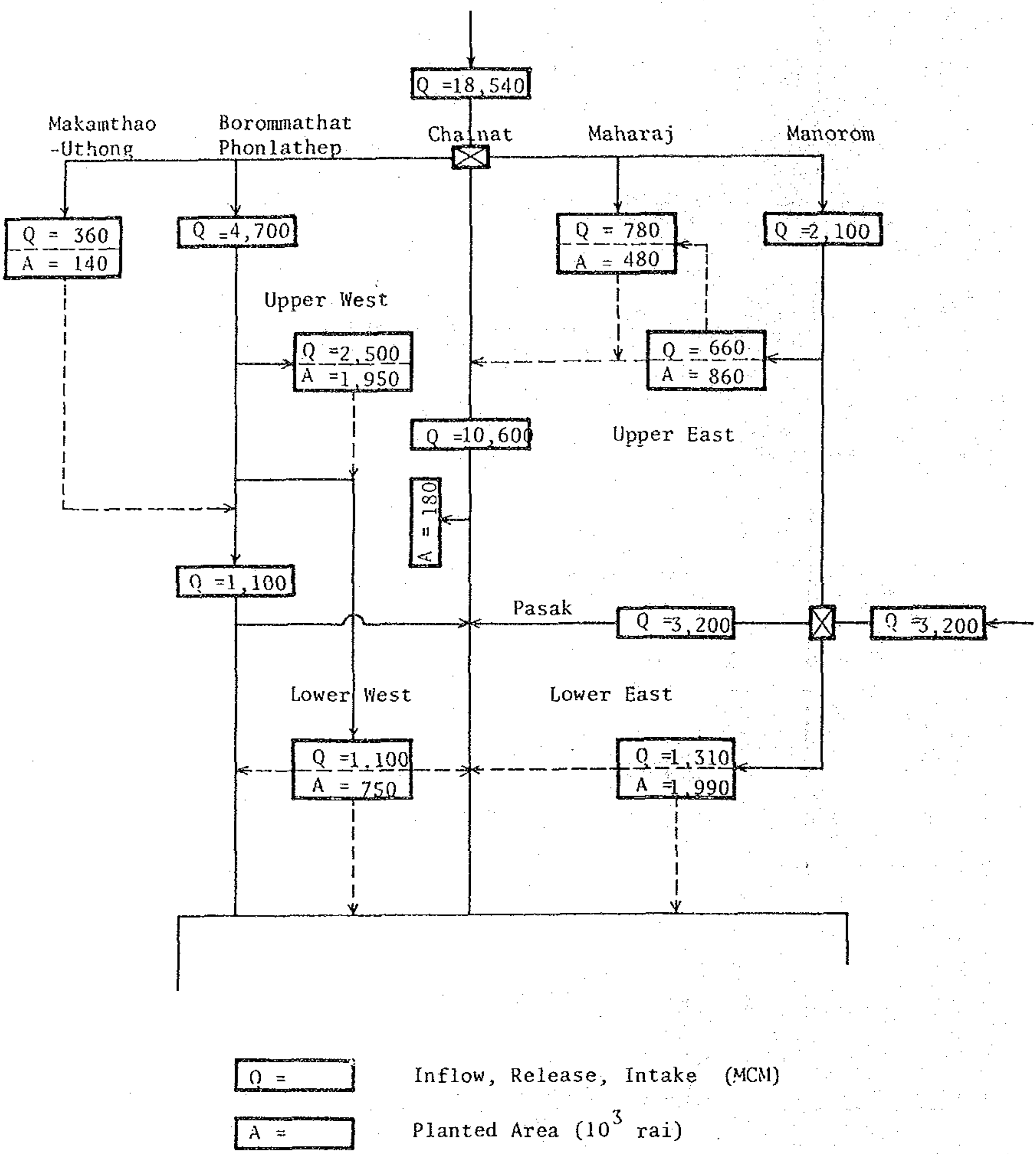


Figure 2-19 IRRIGATION WATER SUPPLY DIAGRAM IN WET SEASON

Dry Season in 1985

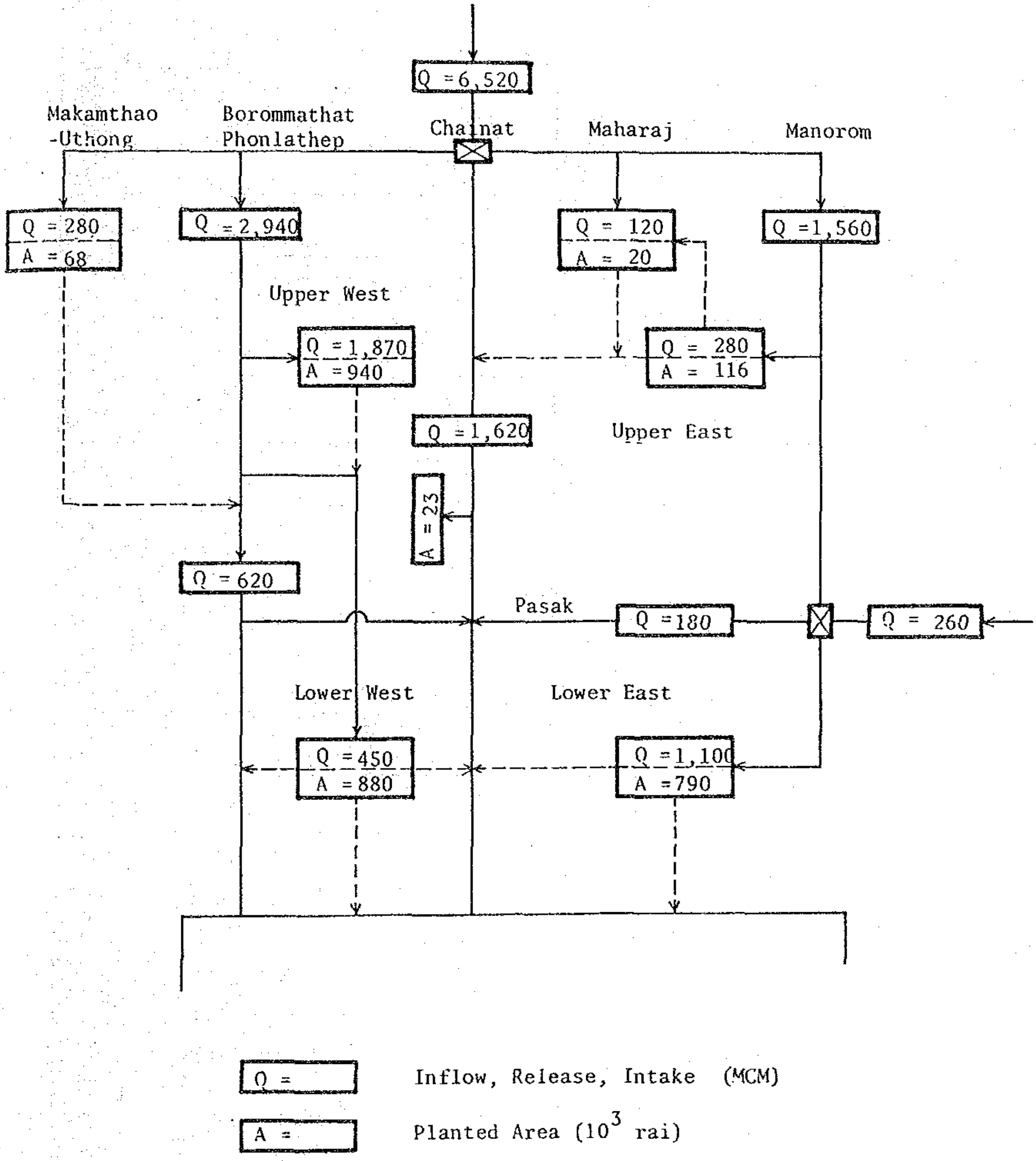


Figure 2-20 IRRIGATION WATER SUPPLY DIAGRAM IN DRY SEASON

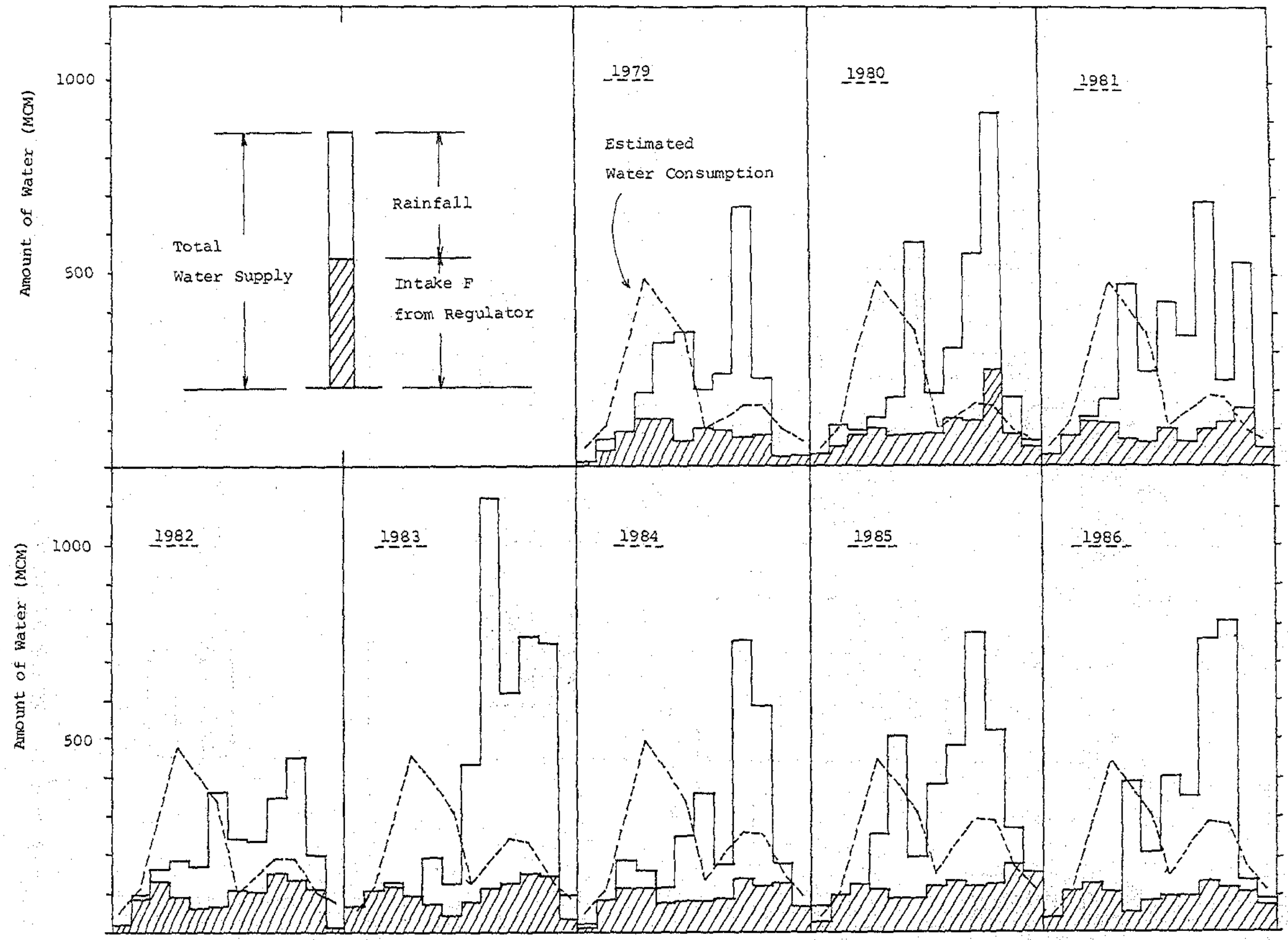


Figure 2-21 RELATION BETWEEN WATER SUPPLY AND CONSUMPTIVE USE IN LOWER WEST BANK

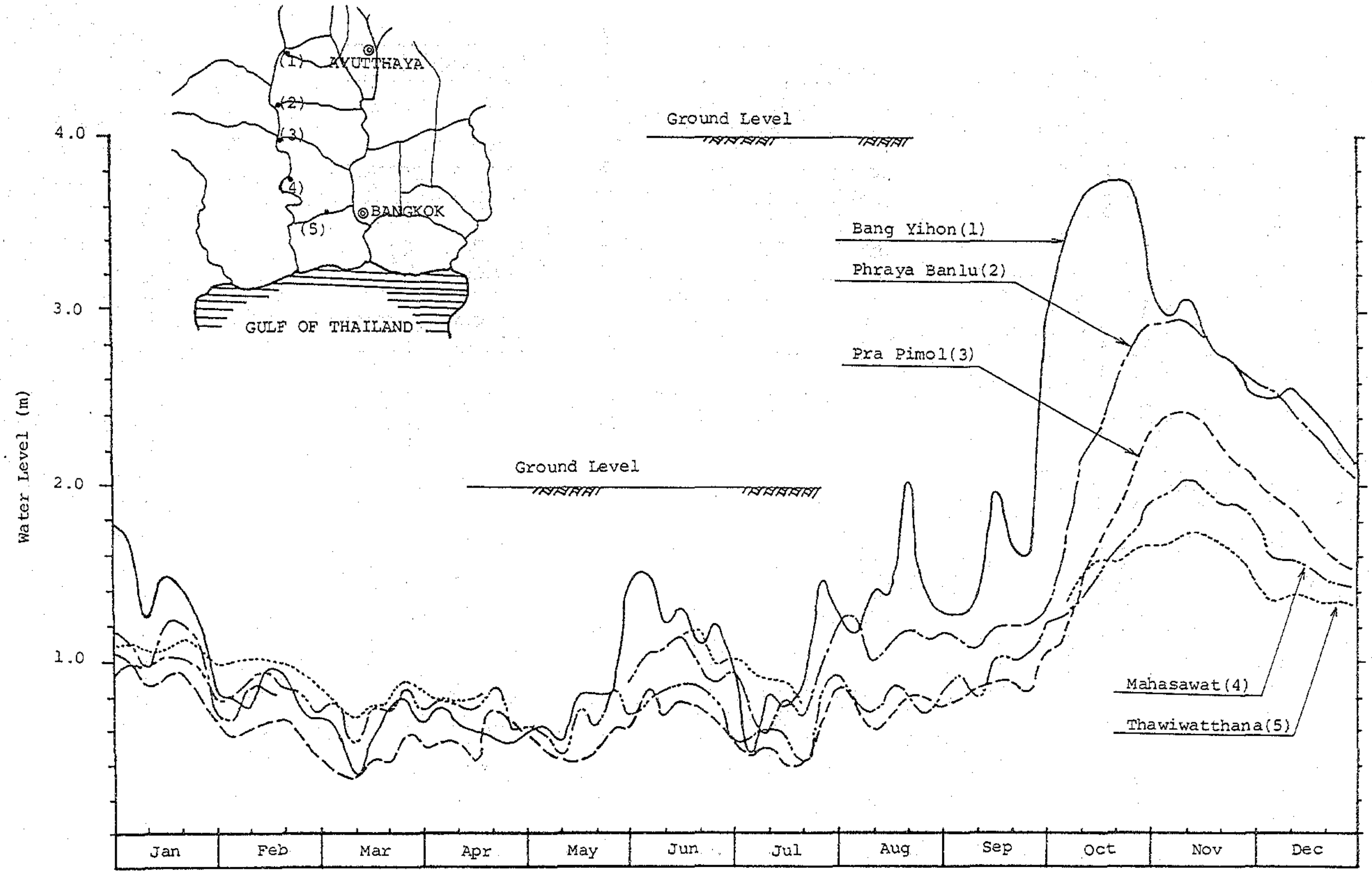


Figure 2-22 WATER LEVEL IN LOWER WEST BANK IN THE CREEK

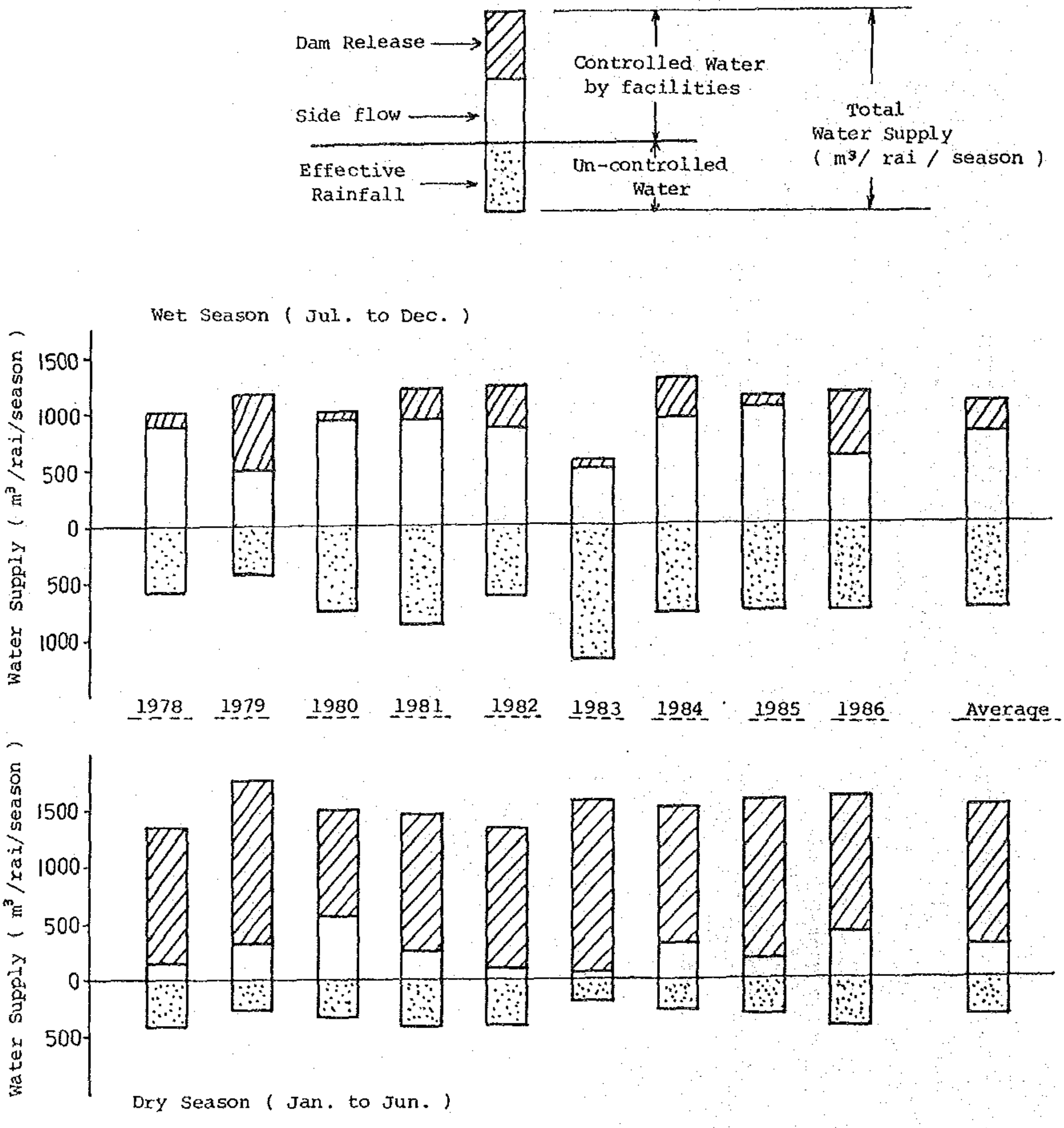


Figure 2-23 COMPONENT OF IRRIGATION WATER SUPPLY

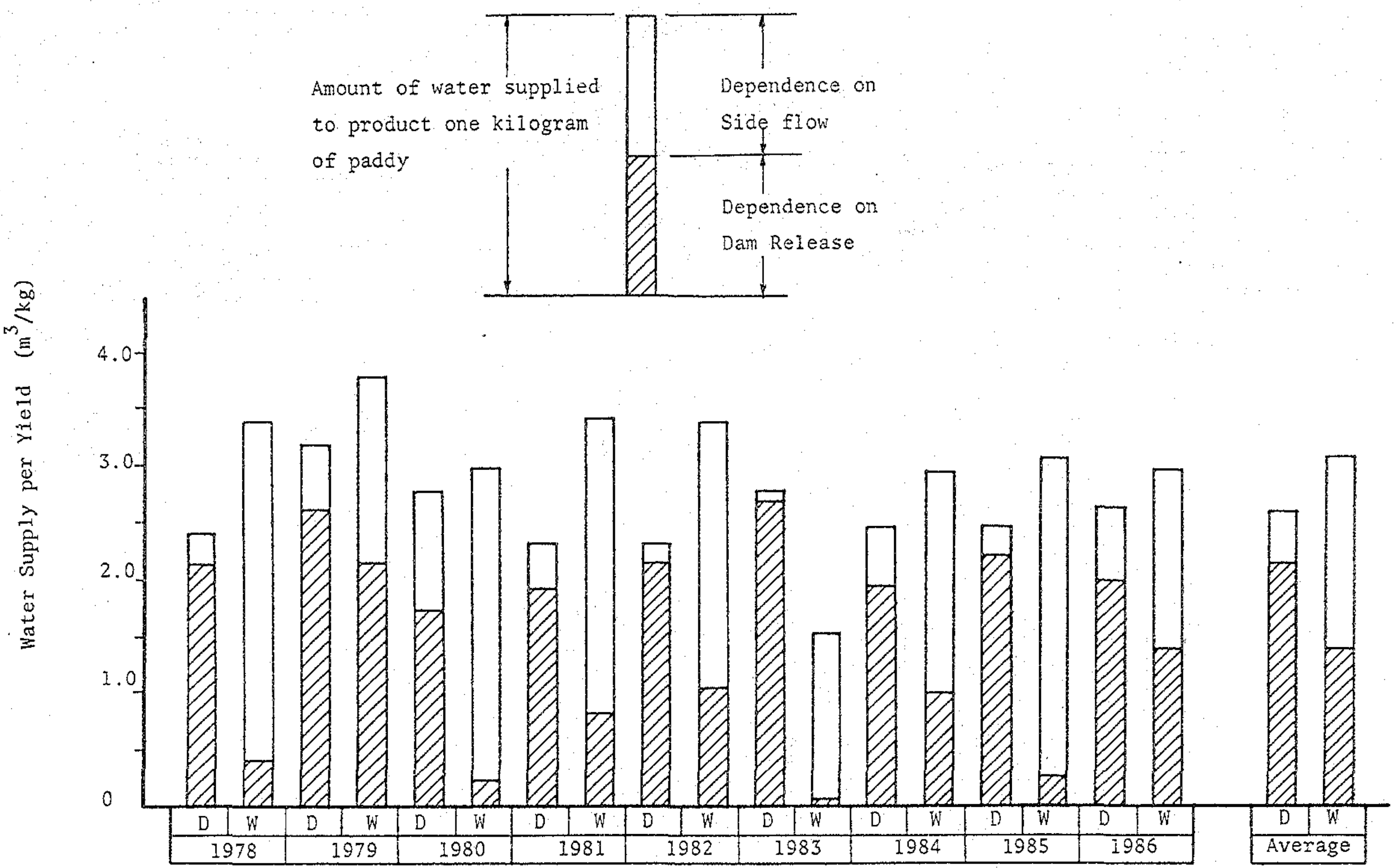


Figure 2-24 COMPONENT OF WATER SUPPLY PER YIELD

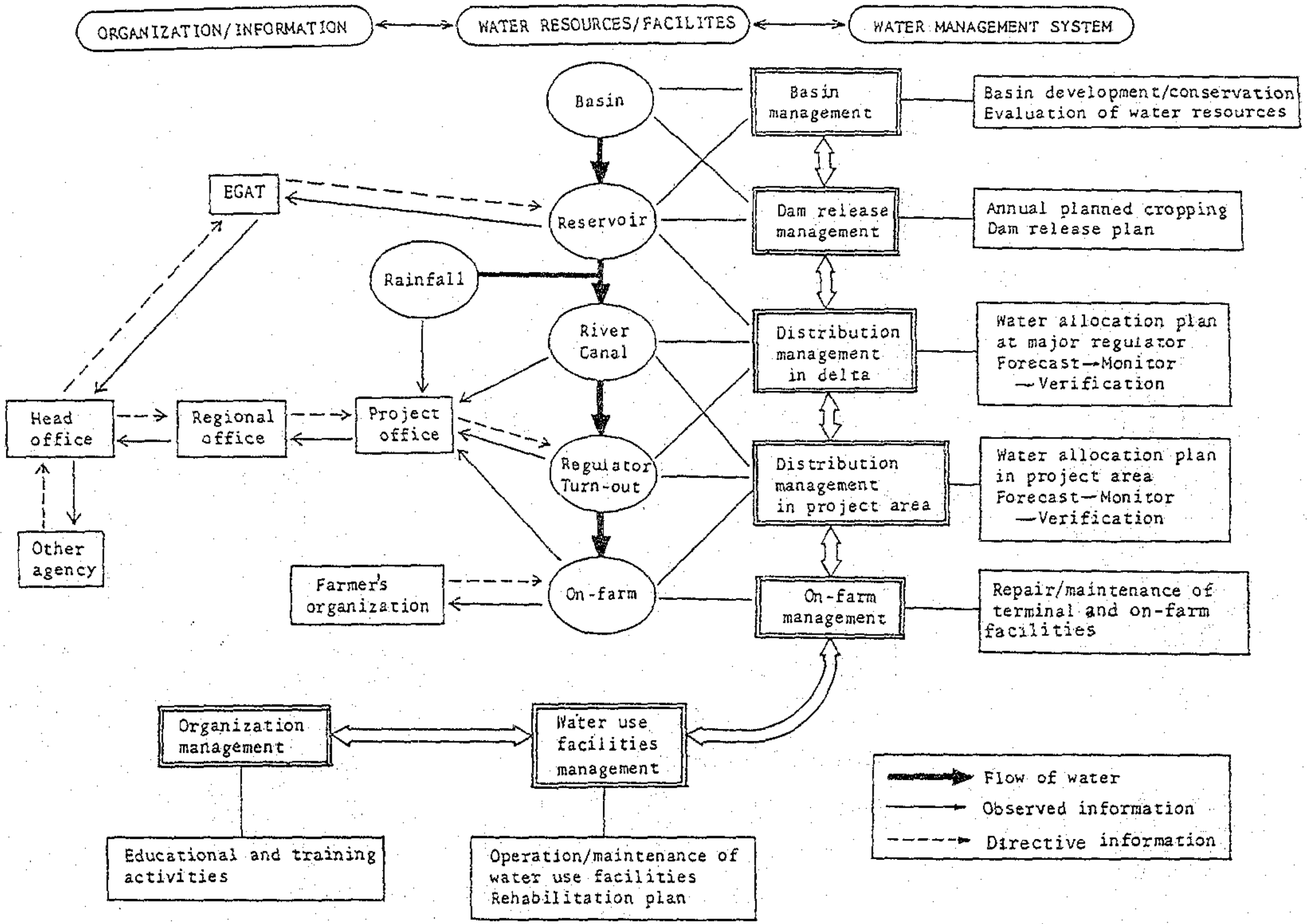


Figure 3-1 BASIC CONCEPT OF WATER MANAGEMENT SYSTEM

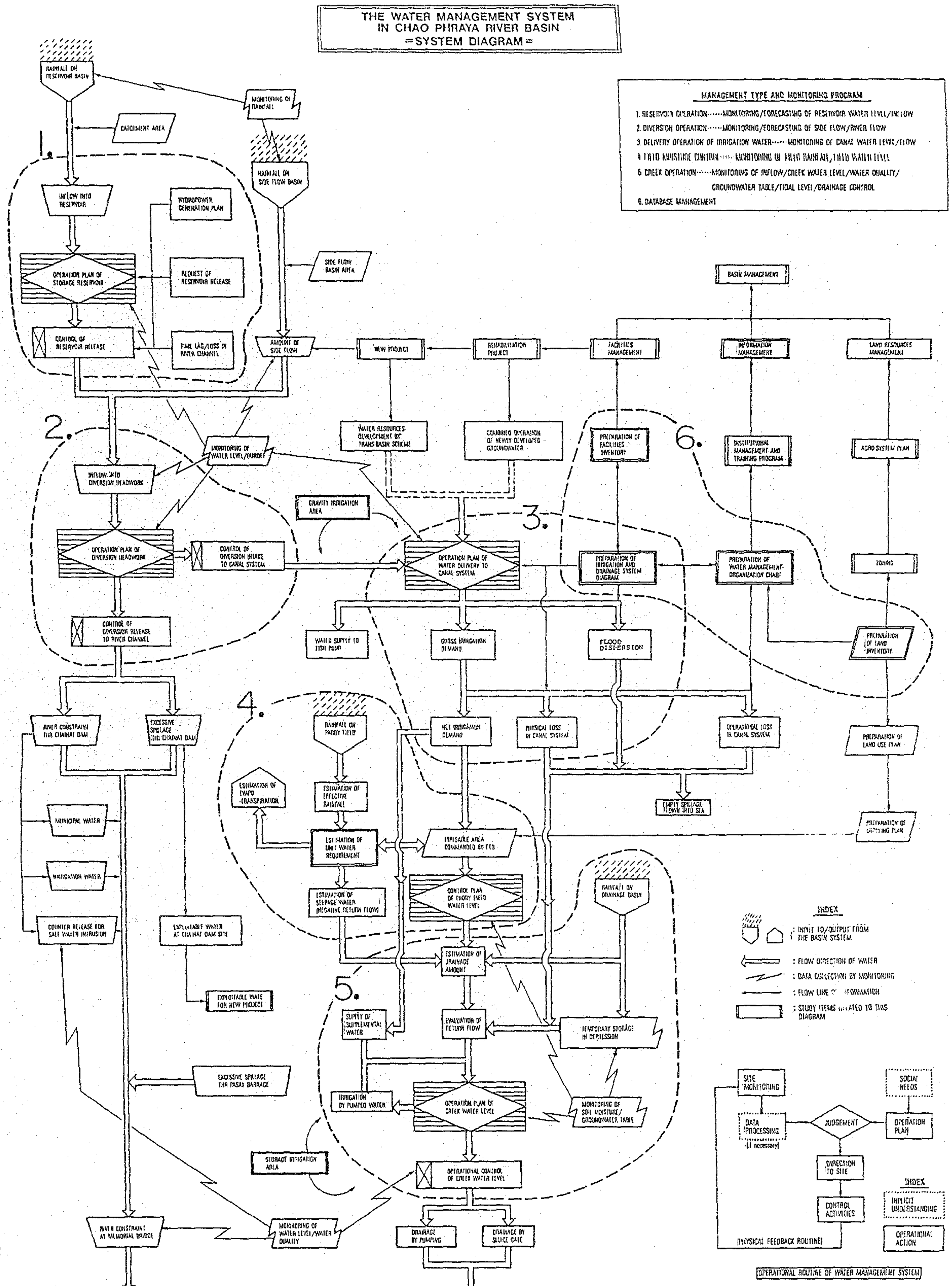


Figure 3-2 THE WATER MANAGEMENT SYSTEM IN CHAO PHRAYA RIVER BASIN - SYSTEM DIAGRAM

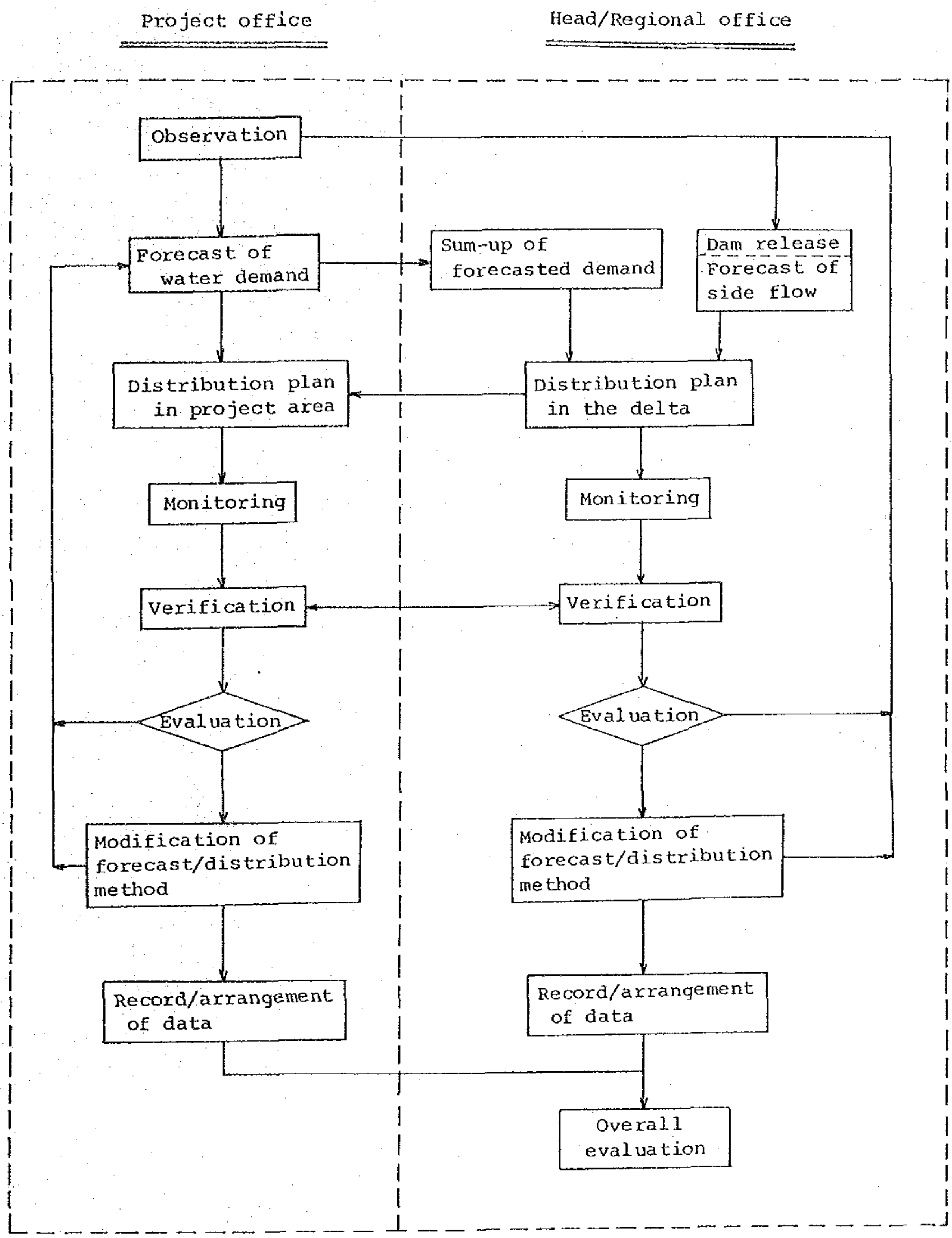


Figure 3-3 SYSTEM FORMATION OF WATER DISTRIBUTION MANAGEMENT