CHAPTER 7.

PROPOSAL FOR MODIFIED OPERATION OF SIRIKIT RESERVOIR

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7.1 Background

In due consideration of the present status of water shortage prevailing in particular in the lower Chao Phraya basin in dry season as well as a decreasing tendency of river flow in both wet and dry seasons observed at the major control points and elsewhere in the Chao Phraya river system, it has been learnt that an urgent measures are to be taken in order to reinforce water supply during dry season. The proposed Kok-Ing-Nan Water Diversion Project has been planned, at the project target year of 2016, to bring about 2,000 MCM of wet season water from the Kok and Ing rivers, which are once stored in the existing Sirikit reservoir and released during dry season in answer to the demand in the lower Nan and the lower Chao Phraya basins.

The Bhumibol and Sirikit reservoirs are presently being operated multipurpose throughout a year for irrigation, hydro-power generation, flood control and river maintenance. As a result of the past operation, the reservoirs have been providing about 5,580 MCM of outflow for downstream uses in dry season and 3,200 MCM mainly for supplemental irrigation in wet season, as an average during the recent 11 years from 1986 to 1996. Of the above amount of water release, the Sirikit reservoir takes charge of 2,540 MCM in dry season and 1,800 MCM in wet season. In order to cope with the immediate needs of additional water release from the reservoir in dry season, the study proposes a modified rule of the Sirikit reservoir operation by means of allocating as much amount of inflow as possible for restoration of the reservoir storage during wet season and releasing it as much as possible during dry season, as a practical solution which can be accomplished before the implementation of the proposed water diversion plan.

To increase water release from the reservoir in dry season, the proposed plan of modification of the Sirikit reservoir operation rule envisages to save the water to be released from the reservoir during wet season, which is almost utilized for supplemental irrigation. It should, therefore, be necessary to take urgent measures to prevent water crisis in wet season, especially for the initial stage of the wet season croppings.

A diagram showing the water budget within the Chao Phraya river system at major control points are presented in Figure 7.1.1 together with calculation chart as per Table 7.1.1. Taking into account the decreasing tendency of river runoff in the recent years, runoffs recorded after 1986 only are tabulated and analyzed.

7.2 Over-view of the Past Reservoir Operation

7.2.1 Limited Inflow into and Outflow from the Reservoir

According to past records of Sirikit reservoir operation for 24 years period from 1974 to 1997, inflow into the reservoir fluctuates from month to month and from year to year as shown in Table 7.2.1. Outflow from the reservoir and storage volume in the reservoir at the end of month are also presented in Tables 7.2.2 and 7.2.3. The following tabulation summarizes annual and seasonal inflows recorded in flood and dry years.

Table 7.2.4 Annual and Seasonal Inflow of Sirikit Reservoir (Unit: MCM)

	Annual Inflow (1)	Dry Season (Dec.-May) (2)	Wet Season (June-Nov.) (3)	Flood Period (July-Oct.) (4)	Rate	
					(3)/(1)	(4)/(3)
1. Average	5,321	717	4,598	4,041	86	88
2. Flood Year						
1975-76	8,573	925	4,600	4,039	89	87
1981-82	7,575	717	7,649	6,669	91	90
1994-95	7,736	623	6,858	6,165	92	91
1995-96	8,401	1,005	7,112	6,446	85	92
3. Dry Year						
1979-80	3,576	508	3,068	2,391	86	78
1987-88	3,237	685	2,552	2,170	79	85
1991-92	3,264	402	2,862	2,434	88	85
1992-93	3,118	563	2,555	2,292	82	90
1993-94	3,326	583	2,743	2,407	83	88

As shown in the above table, wet season inflow occupies 90% and 85% of annual inflow respectively in flood and dry years. About 85% to 90% of the wet season inflow concentrates in the peak flood months from July to October. The reservoir storage restores to its full level or environs during wet season in a flood year, while it hardly recovers in dry years.

Inflow into the Sirikit reservoir in wet season, desirable to be used essentially for restoration of storage, is some 4,600 MCM on an average, of which 2,240 MCM is released downstream for multiple purposes for supplemental irrigation, hydro-power generation and river maintenance. Accordingly only 2,360 MCM of inflow is allocated to restore the storage during this period, resulting quite insufficient recovery of storage at the end of wet season against the total active capacity of 6,660 MCM of the reservoir. This is, in fact, due to the large active capacity of the reservoir which exceeds the annual inflow of 5,300 MCM into the reservoir. The reservoir is so designed and constructed as to store as much inflow as possible within a limit allowable from its topographic situation. As a result, the reservoir was filled with water to its maximum storage level only in exceptional flood years of 1975 and 1995 with flood runoff which corresponds roughly to once in 10 year occurrence, and this is normal operation of the reservoir in Thailand. Particularly in dry years, amount of wet season inflow used for storage restoration was as small as 1,000 MCM, causing severe deficit of outflow in the succeeding dry season. Due to insufficient restoration of reservoir storage in wet season, contribution of the reservoir outflow for downstream beneficial areas in dry season is limited only to 2,830 MCM in the average year.

Table 7.2.5 Present Water Balance of the Sirikit Reservoir (MCM)

Season	Inflow	Storage Consumption	Outflow	Losses
Wet (June-Nov.)	4,600	(-)2,360	2,240	
Dry (Dec.-May)	720	2,110	2,830	
Annum	5,320	(-)250	5,070	360

7.2.2 Large Empty Storage Space in the Reservoir

In theoretical meaning, the reservoir is to be operated in principle in such a way to restore storage during wet season toward the full storage level at the end of wet season. The operational record in the past reveals however that there still remains a great room for additional storage in the reservoir, due to the lack of inflow into the reservoir. The proposed Kok-Ing-Nan Water Diversion Project intends to utilize most efficiently this existing empty storage space of the Sirikit reservoir.

Table 7.2.6 Empty Storage Space in the Reservoir

	Average Year	Dry Year
Empty Space (MCM)	2,360	5,000

7.2.3 Wet Season Allocation of Water

The reservoir has been operated not only for water consumption sectors such as irrigation and domestic/municipal/industrial water supply but also for hydro-power generation. Considerable amount of water were released in the past decade from the reservoir during wet season for power generation, however, during recent years allocation of water to be released from the reservoir has been made under RID's initiative even in wet season.

- In June, reservoir inflow is commonly released downstream without restored in the reservoir since the amount of inflow is relatively smaller than those in July to September and on the other hand supplemental irrigation water is much required for initial period of wet season paddy growth. As a consequence reservoir storage reaches the lowest level from late June till early July.

- The reservoir restores by inflow during the peak flood months from July to October. In a flood year, the reservoir is filled with water to its maximum water level or environs at the time from the beginning to the end of October. On the contrary in dry years, inflow in wet season is adequate only to restore the reservoir at maximum to 40 to 50% of its full capacity.

- Stored by wet season inflow, the reservoir storage reaches the highest level from the beginning to the end of October. In a case when the highest level is around the maximum, the reservoir could release water sufficient to guarantee 60% to 70% of dry season irrigation as projected for the period from November to June of the following year. This is proved by the achievement of 1995/96 dry season cropping in the lower Nan and the Chao Phraya delta. In such a case when storage is insufficient at the end of wet season, dry season outflow is reduced according to availability of storage (Command and Control System).

- Because of exceedingly small inflow in a dry year amounting to about 50% of the average value, a part of storage is left unused as a carry-over storage providing for unforeseen drought in the initial stage of wet season.

7.2.4 Existing Status of Sirikit Reservoir Operation

Operated result of the Sirikit reservoir is shown in Figure 7.2.1. The rule curves for reservoir operation are being set up by EGAT, however, it is found that there are some years when the reservoir was operated lower than the lower rule curve, according to several constraints and/or uncontrollable factors in the course of actual reservoir operation. In the exceptional flood years of 1975 and 1995, the water level exceeded the upper rule curve. Major parameters such as annual lowest storage at the end of June (carry-over storage), inflow during the peak flood months from July to October which is effective for storage restoration, downstream release during the same period and dry season inflow and outflow from November to June are extracted from the past record of reservoir operation as given below.

Table 7.2.7 Storage, Inflow and Outflow at the Sirikit Reservoir (Unit: MCM)

Year	Carry-over at End of June	Inflow from July to October	Outflow from July to October	Storage at End of October	Inflow from Nov. To June	Outflow from Nov. To June	Remark
1975-76	3,592	6,669	2,678	6,700	1,592	5,006	Flood Year
1976-77	3,052	4,621	2,175	5,353	1,495	4,965	
1977-78	1,727	3,020	2,031	2,594	1,328	2,680	
1978-79	1,069	5,187	1,097	4,993	1,510	4,395	
1979-80	1,978	2,391	2,115	2,168	1,036	2,287	Dry Year
1980-81	728	5,130	923	4,743	1,485	4,038	
1981-82	1,980	6,165	2,446	5,604	1,242	4,366	Flood Year
1982-83	2,223	4,147	1,542	4,746	1,146	4,239	
1983-84	1,423	4,067	1,006	4,466	1,562	3,059	
1984-85	2,644	4,995	1,885	5,727	1,261	4,632	
1985-86	2,041	3,951	751	5,215	1,927	3,915	
1986-87	2,927	2,975	1,678	4,187	854	4,037	
1987-88	779	2,170	947	1,912	1,253	1,824	Dry Year
1988-89	1,162	3,330	587	3,826	1,046	2,416	
1989-90	2,242	2,905	1,277	3,789	1,140	3,360	Dry Year
1990-91	1,352	2,896	1,576	2,599	1,033	2,918	Dry Year
1991-92	526	2,434	886	2,008	658	2,346	Dry Year
1992-93	147	2,292	242	2,129	942	2,337	Dry Year
1993-94	552	2,407	1,559	1,346	1,127	1,611	Dry Year
1994-95	699	6,446	579	6,477	1,089	4,423	Flood Year
1995-96	2,889	7,680	3,022	6,590	1,903	5,740	Flood Year
1996-97	2,458	4,421	1,952	4,842	1,075	4,156	
1997-98	1,487	3,684	1,155	3,949	-	-	Dry Year

Some important issues involved in the past operation of the Sirikit reservoir are summarized as follows;

(1) Lowest Storage at the End of June (Carry-over Storage)

It is preferable to set up the carry-over storage as high as possible to preserve storage for unforeseen drought during the initial period of wet season, and on the other hand it is recommendable to maintain the carry-over storage as low as possible in order to keep the capacity to control unforeseen flood during wet season. No one can predict the future and there is no theoretical way to adjust these two objectives conflicting each other. Simulation study is the one to provide acceptable range of adjustment between the two.

(2) Wet Season Outflow from July to October

Quantity of outflow from the reservoir during this period should be adjusted carefully taking into account the availability of inflow and existing storage in the reservoir. Whenever inflow is less than usual and reservoir storage is inadequate, outflow is to be restricted so as to save the storage. This function may be accomplished by the lower rule curve for reservoir operation. It should be carefully investigated together with appropriate countermeasures whether reduction of outflow from the reservoir during this period would give serious problem on water supply for irrigation and other uses or not, since in recent years most of wet season release are for irrigation purpose even though there are considerable volume of side-flow flowing into the Nan river from the residual catchment downstream of the Sirikit dam and rainfall is also effective on the irrigated service area. Generation of hydro power would also decrease as the outflow reduced.

Even tough some other uncontrollable constraints may realize during the actual operation of the reservoir, the upper and lower rule curves are established as a standard or a guideline so as to control storage as well as the amount of outflow. The excessive water is released compulsory from the reservoir when the storage exceed the upper rule curve, and on the contrary outflow is restricted whenever the storage approaches the lower curve. The simulation study of reservoir operation would be useful to establish a guideline on the basis of hydrological situation ever recorded at the location of the reservoir.

(3) Dry Season Outflow from November to June

Water shortage problems prevail during this period over the Chao Phraya river basin covering all water user sectors including irrigation, domestic and municipal water supply and industry with poor distribution of rainfall and river flow. Outflow from the reservoir in this period is therefore quite important for all water users who are eager to receive even a drop of water from the Sirikit reservoir. However, over-estimation of water to be released would cause inadequency of carry-over storage at the end of dry season which would in turn result insufficient restoration of reservoir storage during wet season.

7.3 Saving of Wet Season Irrigation Water

An ideal pattern of operation of the Sirikit reservoir is to restore its storage as much as possible toward the full level at the end of wet season by inflow during peak flood period from July to October, and to release the stored water during consumptive period from December to next June in response to the request from downstream water users. In view of flood control, reservoir water level is also ideal to be the lowest at the end of June when flood runoff begins to flow into the reservoir. In order to ease water stress of the Bhumibol and Sirikit reservoirs in dry season, it is essential to aim better efficiency of water use in wet season, by means of making effective use of side-flow available in the Chao Phraya river system.

7.3.1 Wet Season Water Budget in the Chao Phraya River System

The modification plan of the Sirikit reservoir operation envisages to save the water to be released from the reservoir during wet season and at the same time to generate additional release of water during dry season. The water budget within the Chao Phraya river system as previously shown in Table 7.1.1 and Figure 7.1.1 can be summarized as follows;

- At the Sirikit reservoir, wet season inflow (June to November) in recent years from 1986 to 1996 is averaged at 4,088 MCM with the maximum of 8,401 MCM in 1995 and the minimum of 2,555 MCM in 1992. The outflow during the same period is observed at 1,790 MCM on an average with the maximum of 4,022 in 1995 and the minimum of 569 MCM in 1992.

- At the Naresuan barrage, wet season inflow is recorded at 2,574 MCM with the maximum of 7,601 in 1995 and the minimum of 1,045 MCM in 1992. The amount of water diverted at the Naresuan barrage into the Phitsanulok irrigation project area is 537 MCM on an average, and water released downstream from the barrage is averaged at 2,037 MCM with the maximum of 7,481 MCM in 1995 and the minimum of 666 MCM in 1992.

- There located about 6,370 sq.km of catchment area between the Sirikit reservoir and the Naresuan barrage from where the residual wet season runoff of 784 MCM is recorded. There exist numbers of DEDP's pumping irrigation projects which are diverting considerable amount of wet and dry season water from the main stream of the Nan river. In some dry years such as 1989/90 and 1993/94, water budget within this catchment amounts to negative values meaning that some part of the Sirikit release in addition to the entire volume of it's own residual runoff is consumed within the catchment. However, it also shows that water supply for wet season irrigation would not fall in short if the water of 161 MCM is released from the reservoir.

- At the mouth of the Nan river, wet season flow is averaged at 5,512 MCM with the maximum of 13,187 MCM in 1995 and the minimum of 2,007 MCM in 1988. It should be noted here that this amount of water is the surplus after utilized for various water user sector including irrigation.

- There extends about 14,830 sq.km of the residual catchment between the naresuan barrage and the Nan river end from where a large amount of wet season side-flow, averaged at 3,475 MCM together with the maximum of 7,604 in 1994 and the minimum of 886 MCM in 1988, is produced. This amount of water is also surplus after used in each tributary sub-basins.

- The above figures explain that there is almost no water shortage in the areas along the main stream of the Nan river where the Nan river water can be distributed either under gravity or by pump lifting.

- With the average inflow of 4,303 MCM, the Bhumibol reservoir releases 1,396 MCM of wet season water as an average together with the maximum of 2,723 MCM in

1986 and the minimum of 258 MCM in 1988. There exists a total catchment area of 18,600 sq.km downstream of the Bhumibol dam including the watershed of the Wang river producing 1,944 MCM of wet season runoff. At every major control points along the Ping river, wet season water budget shows the positive values showing that there is also no water shortage during wet season.

- Along the Yom river the similar tendency can be observed showing the average wet season surplus of 3,049 MCM with the maximum of 5,614 MCM in 1994 and the minimum of 1,100 MCM in 1993.

- After the Nan, Ping and Yom rivers join, the Chao Phraya river traverses the central plain southward. Between the confluence of three rivers and Nakhon Sawan there extends about 7,940 sq.km of catchment area where water consumption exceeding it's own runoff has been promoted even in wet season (refer to "Upper Nakhon Sawan Side-flow" in Table 7.1.1).

- Between Nakhon Sawan and Chainat, there extends about 8,430 sq.km of catchment area where water consumption exceeding it's own runoff has also been promoted even in wet season (refer to "Upper Chainat Side-flow" in Table 7.1.1).

- Finally the Chao Phraya river arrives at Chainat from where water is diverted and distributed to serve the Chao Phraya delta area. The wet season flow of the Chao Phraya at Chainat is averaged at 14,155 MCM with the maximum of 31,557 MCM in 1995 and the minimum of 6,255 MCM in 1993.

It may be concluded from above considerations that the wet season water release of about 3,200 MCM from the both Bhumibol and Sirikit reservoirs is to meet the requirements mainly for irrigation in the Lower Chao Phraya basin located downstream of the confluence of three rivers, Nan, Ping and Yom rivers. It is also remarked that the minimum wet season flow of 6,255 MCM recorded at Chainat in 1993 is equivalent nearly to the average dry season flow of 5,843 MCM showing that, even in wet season, availability of river flow is critical in a dry year. This situation would be accelerated more and more in future when a decreasing tendency of river flow and the future promotion of upstream development is taken into consideration. In order to cope with the present and future water crisis, more strict way of water utilization/management even in wet season should be inquired.

7.3.2 Guideline to Allocate Additional Water to Dry Season Release

The only practical way to generate additional release of water from the Sirikit reservoir during dry season under the existing hydrological situation is to save the water released from the reservoir and to promote restoration of storage during wet season, and to release the stored water during dry season, and this is none other than saving water required for wet season irrigation in the lower Chao Phraya basin. The degree of water saving for wet season irrigation may be more or less 20% in a practical manner, and the concrete countermeasures are to be realized in order to achieve this order of water saving. Hence the target is;

Amount of Water Saving for Wet Season Irrigation = 3,200 MCM x 20% = 640 MCM

7.3.3 Countermeasures to Achieve Water Saving

Useful countermeasures to attain the above target would involve 1) improvement of operational practice at regulators/intake facilities and 2) effective use of side-flow;

- Improvement of Operation Practice at Regulators/Intake Facilities

  In the irrigation service area at present, the operation of gates at regulators and intake facilities are being made on a weekly basis. This system allows a considerable amount of operation losses with water only to pass through irrigation canals emptying finally into the sea. More diligent and frequent operation of gates on a daily basis would result effective water saving.

  The improvable change of interval of the gate operation from a week to a day would reduce the amount of irrigation water to be diverted theoretically by about 14% (1/7 = 14%). If appropriate improvement and rehabilitation of the irrigation and water management facilities is accompanied, effect of this improvement would bring a modest value of 400 MCM of water saving (3,200 MCM x 14% = 448 MCM).

- Effective Use of Side-flow

  Judging from the aforementioned evaluation of available flow at the major control points, there still remains plenty of side-flow in the Chao Phraya river system in wet season except a critically dry year. In order to ease water strain of the reservoirs in dry season, it is inevitably necessary to aim effective use of available water resources by means of making better use of side-flow in wet season. Although the expected degree of efficiency depends to a great extent on completeness of water management system, effective use of water resources may be achieved through improved water management system, which enables improved side-flow forecasting and easy and prompt understandings of water behaviors in the river and irrigation systems. The upgrading of water management system for better use of side-flow in wet season will improve water use efficiency from the reservoirs till the main regulators in the irrigable areas by 5 to 10% (Master Plan Study on the Water Management System and Monitoring Program in the Chao Phraya Basin, June, 1989, JICA), resulting a water saving of 240 MCM (3,200 MCM x 7.5% = 240 MCM).

7.4 Sample Operation of the Sirikit Reservoir

In order to achieve the above requirement, a study is carried out showing a sample of the modified operation of the Sirikit reservoir. In the study, reduction of 640 MCM of wet season release and generation of additional release in dry season are shouldered only by the Sirikit reservoir, and operation of the Bhumibol is left as it is.

To quantify the volume of water and its monthly distribution to be released from the Sirikit reservoir during wet season, the following studies are made;

7.4.1 Restrictive Mode of Wet Season Release from the Sirikit Reservoir

The lowest and lower values of the monthly releases during wet season are extracted from the past record of the Sirikit reservoir operation;

Table 7.4.1 Lowest and Lower Monthly Releases from Sirikit Reservoir (MCM)

Month	June	July	Aug.	Sep.	Oct.	Nov.
Minimum	30.2 (1994)	14.5 (1994)	25.7 (1992)	58.0 (1992)	40.1 (1992)	60.0 (1983)
2nd Minimum	63.5 (1988)	118.5 (1992)	101.7 (1994)	59.9 (1991)	42.0 (1983)	113.5 (1985)
3rd Minimum	118.9 (1992)	147.5 (1988)	118.3 (1988)	111.3 (1983)	64.3 (1985)	171.8 (1988)
4th Minimum	**143.6 (1989)**	**168.0 (1989)**	**138.3 (1980)**	**118.3 (1987)**	**72.0 (1987)**	**189.8 (1987)**
5th Minimum	149.9 (1991)	168.0 (1989)	193.0 (1985)	178.0 (1997)	125.5 (1993)	206.0 (1980)

Data period : 1974 - 1997.

As a simple manner, the fourth minimum release during the 20-years period may be used in substitution for the probable drought release from the reservoir which would occur once in five years.

Table 7.4.2 Probable Drought Release from the Sirikit Reservoir (MCM)

	June	July	Aug.	Sep.	Oct.	Nov.
Probable Drought Release (P=1/5)	150	170	140	120	80	190

It is, however, intolerable for the wet season crops under the initial growing stage that the supply of irrigation water is suspended. Taking the present situation of irrigation practice including cropping calendar adopted in the lower Chao Phraya basin, a guideline to set up the water release during the initial period of wet season, June to August, is examined.

In the previous study, the minimum to the fourth minimum releases during these months are observed in 1994, 1992, 1989, 1988 and 1980. The reservoir was operated rather restrictively saving consumption of the storage because of sufficient side-flow in the Nan river downstream of the reservoir in the year 1994 and in August, 1980 as is seen in the paragraph 7.4 of the Supporting Report. On the contrary, the wet season in 1992 was critically dry ever recorded in the past, providing the major reason to exclude this year from further consideration. Examination has therefore narrowed down to the evaluation of the release in June to August in the year 1988 and 1989.

Following procedure was employed to estimate the current available flow of the Nan river downstream of the Sirikit dam;

Figure 7.4.1 Schematic Diagram of Nan River System Downstream of Sirikit Dam

(1) Qo: Outflow from Sirikit Dam, Actually Observed (Table 7.4.1, Supporting Report)
(2) Q7: Nan River Flow Actually Measured at Station N7 (Table 7.4.2, -do-)
(3) Qn: Water Diverted at Naresuan Barrage, Actually Observed (Table 7.4.3, -do-)
(4) Qe: Nan River Flow at the Confluence with Ping River (Table 7.4.4, -do-)
Qe=Q7*34,330sq.km/29,153sq.km=Q7*1.178
(5) Qr: Nan River Sideflow downstream of Sirikit Dam (Table 7.4.5, -do-)
Qr=Qe+Qn-Qo

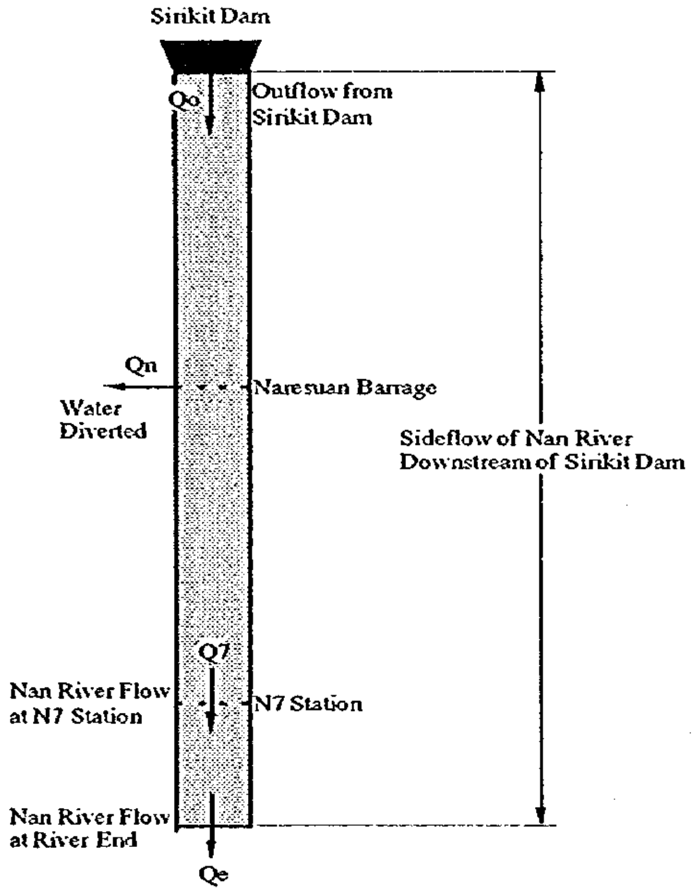

Table 7.4.3 Current Available Flow of Nan River Downstream of Sirikit Reservoir

Month	Sirikit Release	Nan Side-flow	Naresuan Diversion	Flow at the End of Nan River	Remark
June	260	631	7	884	
July	290	412	50	651	
August	366	889	122	1,134	
September	337	1,464	137	1,664	
October	242	963	143	1.062	
November	359	330	98	592	
Total	1,854	4,689	557	5,987	

Note: Data period = 1974-1995, unit = MCM/month.

As is seen in the above table, 650 to 1,100 MCM/month of flow on average is maintained during the first half of wet season at the end of the Nan river. During the same period, 410 to 890 MCM/month of side-flow is available from the residual catchment of Nan river downstream of the Sirikit reservoir. A simple assumption is employed that this order of the Nan river flow is considered to be sufficient to answer for cultivation of wet season paddy in the lower Nan basin and Chao Phraya delta. The responsibility of the Sirikit reservoir for release of wet season water is to secure about 800 MCM/month of flow in the Nan river, and therefore the amount of water to be released from the reservoir is calculated as under;

Table 7.4.4 Water to be Released from Sirikit Reservoir to Maintain the Nan Flow (MCM)

	June	July	Aug.	Sept.	Oct.	Nov.	Total
Nan Side-flow	630	410	890	1,460	960	330	4,680
Sirikit Release	170	390	0	0	0	470	1,030

The above table is compared with the probable drought release corresponding to 1/5 probability to determine the allocation of water release from the Sirikit reservoir during wet season.

Table 7.4.5 Allocation of Monthly Release from Sirikit Reservoir (MCM)

	June	July	Aug.	Sep.	Oct.	Nov.	Total
From Downstream Requirement	170	390	0	0	0	470	1,030
From Past Achievement	150	170	140	120	80	190	850
Monthly Minimum Release	170	390	140	120	80	470	1,370

7.4.2 Allocation of Water Release during Dry Season

Because of insufficient annual inflow into the reservoir, the reservoir outflow during dry season should be adjusted in accordance with available storage in the reservoir. Currently, the

Water Management Branch, Operation and Maintenance Division of RID estimates the water budget according to information on water budget of the two strategic storages, Bhumibol and Sirikit, given by EGAT and the information on dry season production requirements from MOAC, estimated water uses for domestic and industrial purposes as well as uses of navigation and protection of sea water intrusion. RID then estimates water uses for inter-sectoral activities during dry season. As for agricultural water use, RID has established rules and guidelines to allocate water (Command and Control System). According to the past achievement of this Command and Control System, and considering the available active storage in the reservoir at the end of wet season and appropriate carry-over capacity of about 1,500 MCM at the end of dry season, the following plan to control the dry season outflow from the reservoir is tentatively established;

Table 7.4.6 Water Release from Sirikit Reservoir during Dry Season

Month	Rate (%)	Active Storage Available at the End of November (MCM)				
		>6,000	6,000 to 5,000	5,000 to 4,000	4,000 to 3,000	<3,000
Dec.	12	540	480	360	240	180
Jan.	23	1,035	920	690	460	345
Feb.	27	1,215	1,080	810	540	405
Mar.	23	1,035	920	690	460	345
Apr.	11	495	440	330	220	165
May	4	180	160	120	80	60
Total	100	4,500	4,000	3,000	2,000	1,500

7.4.3 Proposed Operation Rule Curves

The operation of a reservoir during dry season is undertaken in a way that two purposes confronting each other can be adjusted. The first objective is to promote water release effectively in response to the demand of the service area. For this purpose, the reservoir is ideal to be full of storage at the beginning of dry season. However, as a result, promotion of water release accelerates consumption of available storage in the reservoir. Secondly some countermeasures for unforeseen drought is needed. In preparation for the present and future drought, water release is rather restricted intending preservation and restoration of the storage. This procedure is made in conformity with the lower rule curve for reservoir operation.

During wet season when inflow into the reservoir largely exceeds water demand under normal condition, the reservoir should be so operated that i) as much storage capacity as possible be secured to regulate unforeseen flood runoff, ii) as small amount of water as possible be wasted through spillage and iii) reservoir level be finally recovered to the full water as frequent as possible at the end of wet season. The upper rule curve is to be set up in order to cope with the above requirements.

The upper and lower rule curves are preliminarily established through trial and error as follows;

Table 7.4.7 Proposed Upper Rule Curve of Reservoir Operation

Month	June	July	Aug.	Sep.	Oct.	Nov.
Storage (MCM)	2,150	2,900	4,200	5,650	6,300	6,660

Table 7.4.8 Proposed Lower Rule Curve for Reservoir Operation

Month	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Storage (MCM)	2,900	2,950	2,800	2,450	2,000	1,350	1,000

7.4.4 Result of Sample Operation Study

The operation study is made through simulation of balance of water flowing into and released from the Sirikit reservoir with conditions mentioned above. The simulated results are as per Figure 7.4.2 to 3 and Table 7.4.6 of the Supporting Report. About 650 MCM of water could be released from the reservoir during dry season in addition to the present achievement of 2,830 MCM amounting to a total release of 3,480 MCM. About 360 MCM of flood control capacity will also be added to the present capacity of 4,800 MCM for unforeseen flood during wet season. It is noted here that deviations of flood control capacity from the mean annual value are distributed within a range of ±500 MCM under the improved situation of reservoir operation.

Table 7.4.9 Comparative Table of Water Balance at Sirikit Reservoir (MCM)

	Existing Situation	Improved Situation	Increase
Dry Season Outflow	2,830	3,480	650
Flood Control Capacity	4,800	5,160	360
Power Generated, GWh	820	910	90

It is strongly recommended that a proper time step should be employed to arrive at the final target for modification of the operation rule as shown in the sample operation. Gradual improvement of the reservoir operation with a 100 MCM-order of increase of dry season release may be recommended.

Figure 7.1.1 Available Flow in the Chap Phraya River System in the Recent Years

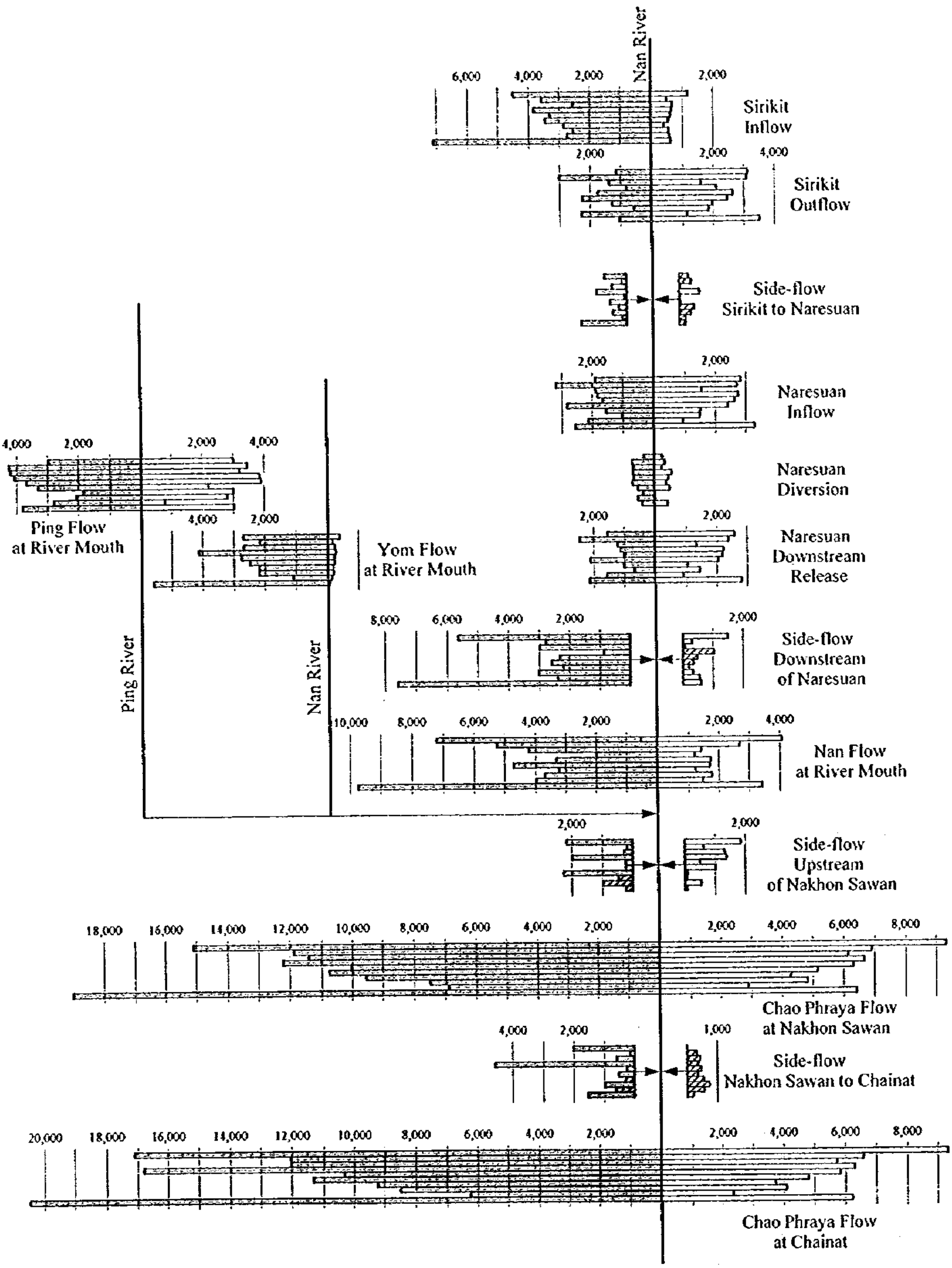

Table 7.1.1 Runoff of Wet and Dry Season at Major Stations in the Chao Phraya Basin

(Unit : MCM)

Year	Sirikit Reservoir						Sirikit to Naresuan Side-flow			Naresuan Barrage									Naresuan to River End Side-flow		
	Inflow			Outflow						Inflow			Water Diversion			Downstream Release					
	Wet	Dry	Total	Wet	Dry	Total	Wet	Dry	Total	Wet	Dry	Total	Wet	Dry	Total	Wet	Dry	Total	Wet	Dry	Total
1985-86	4,517	1,170	5,687	1,164	3,120	4,284	754	-290	464	1,918	2,830	4,748	354	248	602	1,564	2,582	4,146	5,653	1,490	7,143
1986-87	3,593	485	4,078	3,028	3,102	6,130	175	-392	-217	3,203	2,710	5,913	731	334	1,065	2,472	2,376	4,848	2,788	312	3,100
1987-88	2,552	685	3,237	1,403	1,570	2,973	511	-32	479	1,914	1,538	3,452	687	231	918	1,227	1,307	2,534	2,995	92	3,087
1988-89	3,843	643	4,486	822	2,100	2,922	1,017	656	1,673	1,839	2,756	4,595	718	541	1,259	1,121	2,215	3,336	886	-1,028	-142
1989-90	3,316	605	3,921	1,762	2,644	4,406	-89	-20	-109	1,673	2,624	4,297	682	436	1,118	991	2,188	3,179	2,333	-472	1,861
1990-91	3,476	552	4,028	2,272	2,446	4,718	571	-39	532	2,843	2,407	5,250	723	360	1,083	2,120	2,047	4,167	2,608	-348	2,260
1991-92	2,862	402	3,264	1,297	1,967	3,264	275	-481	-206	1,572	1,486	3,058	551	476	1,027	1,021	1,010	2,031	2,206	204	2,410
1992-93	2,555	563	3,118	569	1,836	2,405	476	-375	101	1,045	1,461	2,506	379	32	411	666	1,429	2,095	3,040	332	3,372
1993-94	2,743	583	3,326	2,301	1,123	3,424	-161	-212	-373	2,140	911	3,051	551	26	577	1,589	885	2,474	2,405	554	2,959
1994-95	7,112	624	7,736	1,055	3,504	4,559	1,512	-222	1,290	2,567	3,282	5,849	413	420	833	2,154	2,817	4,971	7,604	598	8,202
1995-96	8,401	1,005	9,406	4,022	4,476	8,498	3,579	-229	3,350	7,601	4,247	11,848	120	609	729	7,481	3,638	11,119	5,706	1,513	7,219
Mean	4,088	665	4,753	1,790	2,535	4,326	784	-149	635	2,574	2,387	4,961	537	338	875	2,037	2,045	4,082	3,475	295	3,770

Year	Nan River at River Mouth			Ping River at River Mouth			Yom River at River Mouth			Upper Nakhon Sawan Side-flow			Chao Phraya River at Nakhon Sawan			Upper Chainat Side-flow			Chao Phraya River at Chainat		
	Wet	Dry	Total	Wet	Dry	Total	Wet	Dry	Total	Wet	Dry	Total	Wet	Dry	Total	Wet	Dry	Total	Wet	Dry	Total
1985-86	7,217	4,072	11,289	2,979	3,008	5,987	2,717	390	3,107	2,184	1,858	4,042	15,097	9,328	24,425	2,024	-2	2,022	17,121	9,326	26,447
1986-87	5,260	2,688	7,948	4,264	3,454	7,718	2,170	148	2,318	192	610	802	11,886	6,901	18,787	156	-314	-158	12,042	6,587	18,629
1987-88	4,222	1,399	5,621	4,212	3,200	7,412	2,698	224	2,922	281	1,320	1,601	11,413	6,144	17,557	612	-419	193	12,025	5,725	17,750
1988-89	2,007	1,187	3,194	4,088	3,850	7,938	4,129	258	4,387	2,006	1,376	3,382	12,230	6,671	18,901	4,587	-366	4,221	16,817	6,305	23,122
1989-90	3,324	1,716	5,040	3,708	3,896	7,604	2,774	204	2,978	251	485	736	10,057	6,301	16,358	274	-456	-182	10,331	5,845	16,176
1990-91	4,728	1,699	6,427	3,320	2,214	5,534	2,498	210	2,708	241	1,025	1,266	10,787	5,148	15,935	546	-344	202	11,333	4,804	16,137
1991-92	3,227	1,214	4,441	1,850	3,001	4,851	2,195	167	2,362	2,285	-90	2,195	9,557	4,292	13,849	-323	-561	-884	9,234	3,731	12,965
1992-93	3,706	1,761	5,467	2,083	2,812	4,895	2,202	192	2,394	-492	68	-424	7,499	4,833	12,332	1,005	-736	269	8,504	4,097	12,601
1993-94	3,994	1,439	5,433	2,805	794	3,599	1,100	120	1,220	-996	535	-461	6,903	2,887	9,790	-648	-555	-1,203	6,255	2,332	8,587
1994-95	9,758	3,415	13,173	3,819	3,023	6,842	5,614	70	5,684	-249	-89	-338	18,941	6,418	25,359	1,546	-196	1,350	20,487	6,222	26,709
1995-96	13,187	5,151	18,338	3,609	4,132	7,741	5,447	279	5,726	5,631	144	5,775	27,874	9,707	37,581	3,683	-403	3,280	31,557	9,304	40,861
Mean	5,512	2,340	7,852	3,340	3,035	6,375	3,049	206	3,255	1,030	658	1,689	12,931	6,239	19,170	1,224	-396	828	14,155	5,843	19,999

SideFlow2

Figure 7.2.1 Sirikit Reservoir Operation Curve

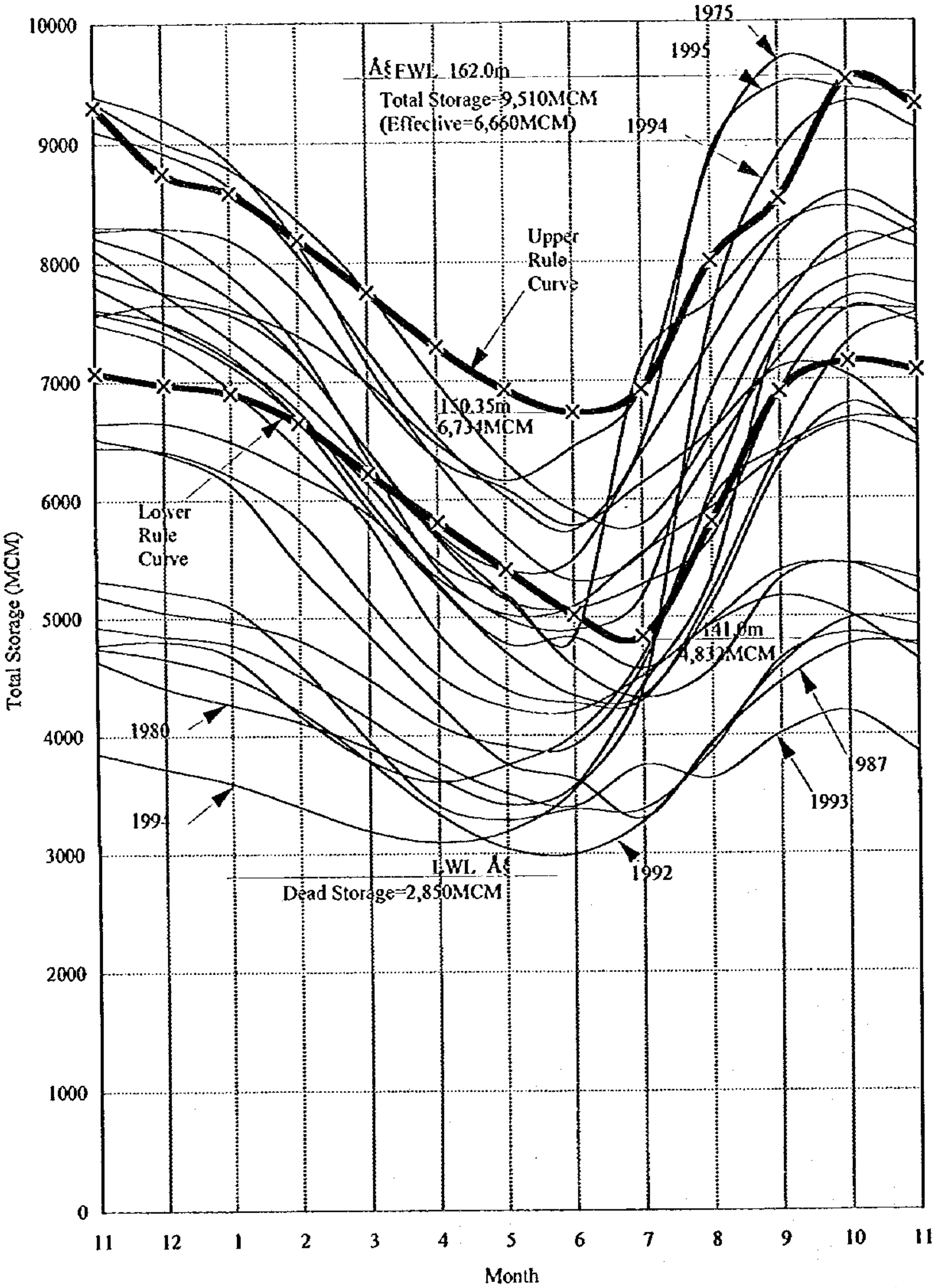

Table 7.2.1 Sirikit Reservoir Inflow

Year	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Wet S.	Dry S.	Annual
1974	191.9	247.7	297.4	399.5	1295.8	885.0	401.9	225.6	127.7	157.7	94.6	94.9	3505.2		4419.7
1975	64.3	184.4	669.4	1091.4	2767.3	1923.6	886.7	311.0	167.0	167.4	170.3	126.7	7649.4	723.6	8529.5
1976	107.3	186.0	356.7	599.9	1431.0	1596.5	993.4	369.8	223.0	202.4	77.2	138.0	5347.3	924.7	6281.2
1977	117.9	217.7	148.6	529.7	998.2	1047.3	444.8	265.5	144.0	122.2	98.8	94.8	3434.1	976.2	4229.5
1978	128.8	117.6	356.1	1004.8	1803.8	1642.9	735.1	250.2	139.9	123.4	61.0	96.4	5792.9	706.2	6460.0
1979	69.7	237.2	532.0	306.2	1084.8	687.7	311.5	145.8	92.0	95.7	43.5	78.1	3068.0	727.6	3684.2
1980	69.0	130.1	382.2	1069.1	1129.6	2427.2	503.6	223.1	134.7	100.1	34.0	99.1	5734.8	508.4	6301.8
1981	79.1	435.3	379.9	2792.4	1583.4	1171.2	618.4	313.0	155.4	130.7	114.3	55.2	6858.3	882.3	7828.3
1982	137.0	124.6	212.2	695.4	1069.2	1457.4	924.8	255.5	115.1	101.6	69.2	74.6	4614.5	717.2	5236.6
1983	112.7	221.4	196.3	572.2	1251.3	1347.4	896.2	328.8	159.2	129.8	120.2	106.1	4592.2	694.6	5441.6
1984	121.6	221.0	375.5	1230.3	1500.3	1637.4	626.7	270.6	136.5	126.8	104.7	95.0	5640.8	857.9	6446.4
1985	128.8	179.1	219.8	589.7	1868.0	1053.6	439.4	346.8	168.4	124.3	115.1	131.8	4517.3	770.9	5364.8
1986	164.1	466.2	410.2	912.7	865.7	812.1	384.3	208.0	121.4	75.9	66.4	72.1	3593.0	1169.9	4559.1
1987	61.6	88.0	160.6	142.1	951.6	661.1	414.9	221.7	89.8	78.8	66.0	50.0	2552.0	485.4	2986.2
1988	89.2	310.8	346.5	817.7	1464.3	635.6	413.6	165.3	103.5	74.1	76.1	63.1	3843.0	684.6	4559.8
1989	47.2	279.4	237.2	642.8	828.4	941.2	492.3	173.7	93.0	84.0	80.4	59.4	3315.6	643.4	3959.0
1990	48.6	239.9	360.7	730.5	884.0	885.6	395.5	219.8	97.2	86.4	44.6	29.3	3476.1	605.3	4022.1
1991	67.9	226.7	260.8	347.9	826.5	846.4	413.1	167.4	85.6	82.0	66.5	64.2	2862.1	552.1	3455.0
1992	44.5	58.7	88.7	417.3	691.8	742.1	441.1	174.4	147.4	93.8	49.4	77.1	2555.4	401.5	3026.3
1993	69.9	125.6	204.2	788.6	642.9	653.1	322.4	132.0	81.6	65.5	58.4	92.2	2743.2	563.2	3236.4
1994	67.3	218.0	411.5	875.2	3273.3	1665.7	631.9	254.5	184.2	119.5	85.0	51.5	7112.1	583.0	7837.6
1995	51.0	132.3	210.7	1018.7	3300.8	2615.1	744.9	510.8	213.2	158.8	149.6	129.9	8401.0	623.5	9235.8
1996	158.0	195.0	388.0	886.0	1593.0	1197.0	745.0	316.0	173.0	136.0	108.0	59.0	5125.0	1004.5	5954.0
1997	93.0	111.0	79.0	462.0	1125.0	1368.0	739.0	249.0	138.0	124.0	81.0	88.0	4022.0	680.0	4657.0
1998	100.0	122.0	146.0	504.0	657.0									653.0	
Average	95.4	206.4	303.5	788.4	1426.3	1245.8	580.0	254.1	137.1	115.0	84.8	84.4	4598.1	716.8	5321.3
Max.	191.9	466.2	669.4	2792.4	3300.8	2615.1	993.4	510.8	223.0	202.4	170.3	138.0	8401.0	1169.9	9235.8
Min.	44.5	58.7	79.0	142.1	642.9	635.6	311.5	132.0	81.6	65.5	34.0	29.3	2552.0	401.5	2986.2

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Table 7.2.2 Sirikit Reservoir Outflow

Year	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Wet S.	Dry S.	Annual
1974	179.8	361.8	373.8	607.6	680.1	489.1	415.9	295.3	276.0	273.8	298.4	467.3	2861.8		4718.9
1975	573.0	440.3	350.0	599.2	728.5	709.2	640.8	494.4	467.9	341.1	546.2	702.0	3522.1	2328.8	6592.6
1976	825.6	814.6	814.1	625.8	623.2	476.4	449.5	443.4	530.5	533.8	545.6	713.8	3432.4	3697.4	7396.3
1977	713.6	752.4	732.2	723.4	737.4	268.0	301.9	527.4	267.2	192.8	238.9	414.4	3290.3	3789.7	5869.6
1978	478.4	258.7	302.1	311.2	206.4	286.3	292.8	276.2	376.0	410.2	490.1	855.8	1675.0	1850.4	4544.2
1979	793.1	734.8	458.8	553.9	673.4	417.8	469.5	519.2	307.7	213.2	175.3	277.4	3092.6	3660.0	5594.1
1980	296.6	309.4	188.1	192.4	138.3	286.9	305.5	206.0	258.3	376.1	472.1	626.4	1317.2	1579.6	3656.1
1981	714.4	646.9	737.6	429.9	1061.7	536.3	418.4	527.7	322.8	416.7	604.7	792.8	3711.6	3094.2	7209.9
1982	848.6	587.3	265.3	470.8	656.5	199.6	215.5	339.8	262.0	456.8	550.6	679.5	2147.5	3572.9	5532.3
1983	997.2	665.9	287.5	524.7	328.2	111.3	42.0	60.0	47.6	187.2	478.2	776.8	1353.7	3612.0	4506.6
1984	756.2	488.7	263.9	345.2	602.4	708.8	228.1	517.9	164.6	457.0	665.4	971.7	2666.3	2734.7	6169.9
1985	983.0	573.3	299.5	270.3	193.0	223.6	64.3	113.5	126.7	192.9	544.3	850.0	1164.2	3815.0	4434.4
1986	728.7	677.7	681.6	555.2	397.2	303.3	422.6	668.4	233.3	319.3	686.9	657.8	3028.3	3120.3	6332.0
1987	633.5	571.4	266.2	452.5	303.7	118.3	72.0	189.8	45.9	192.6	542.5	412.3	1402.5	3102.2	3800.7
1988	237.1	140.0	63.5	147.5	118.3	180.3	140.7	171.8	77.3	210.9	339.8	356.9	822.1	1570.4	2184.1
1989	556.4	558.8	143.6	168.0	430.8	475.5	202.9	341.0	105.4	267.0	428.8	727.4	1761.8	2100.1	4405.6
1990	635.8	479.8	374.8	410.9	411.9	430.6	322.1	321.4	169.8	209.1	506.7	656.0	2271.7	2644.2	4928.9
1991	586.7	318.1	149.9	331.8	312.8	59.9	181.7	261.0	160.1	215.6	340.3	465.9	1297.1	2446.4	3383.8
1992	464.4	320.2	118.9	118.5	25.7	58.0	40.1	207.9	210.7	148.9	292.8	412.8	569.1	1966.5	2418.9
1993	417.5	353.2	293.5	427.5	735.4	260.9	125.5	458.4	195.9	174.5	238.2	274.9	2301.2	1835.9	3955.4
1994	136.7	102.5	30.2	14.5	101.7	302.4	160.0	446.2	341.5	369.2	629.0	820.4	1055.0	1122.7	3454.3
1995	745.6	598.7	472.6	268.1	823.3	1177.4	753.6	526.7	377.5	484.4	798.3	1082.4	4021.7	3504.4	8108.6
1996	939.0	794.0	738.0	646.0	734.0	359.0	213.0	374.0	244.0	383.0	615.0	775.0	3064.0	4475.6	6814.0
1997	721.0	634.0	410.0	446.0	332.0	178.0	199.0	463.0	339.0	421.0	659.0	659.0	2028.0	3372.0	5461.0
1998	614.0	331.0	226.0	157.0	335.0									3023.0	
Average	623.4	507.6	367.3	401.7	473.2	359.0	278.2	364.6	246.2	310.3	487.0	642.9	2244.1	2825.9	5061.3
Max.	997.2	814.6	814.1	723.4	1061.7	1177.4	753.6	668.4	530.5	533.8	798.3	1082.4	4021.7	4475.6	8108.6
Min.	136.7	102.5	30.2	14.5	25.7	58.0	40.1	60.0	45.9	148.9	175.3	274.9	569.1	1122.7	2184.1

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Table 7.2.3 Sirikit Reservoir Storage Volume at the End of Month

Year	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Wet S.	Dry S.	Annual
1974	7674	7458	7352	7102	7674	8065	8025	7928	7753	7613	7388	6988	7691		7585
1975	6474	6160	6442	6918	8835	9680	9550	9345	9015	8795	8360	7758	8462	7063	8111
1976	6990	6318	5902	5786	6552	7590	8203	8113	7743	7358	6885	6272	7024	7873	6976
1977	5694	5168	4577	4318	4565	5322	5444	5189	5047	4963	4807	4474	4903	6520	4964
1978	4083	3911	3919	4597	6086	7378	7843	7803	7505	7184	6751	5994	6271	4548	6088
1979	5284	4777	4828	4563	4940	5172	5018	4635	4405	4264	4113	3890	4859	6249	4657
1980	3627	3414	3578	4425	5355	7388	7593	7588	7425	7140	6691	6126	5988	3952	5863
1981	5468	5193	4830	7137	7663	8279	8454	8216	8022	7711	7187	6410	7430	6341	7048
1982	5666	5150	5073	5277	5672	6910	7596	7488	7318	6937	6426	5789	6336	6691	6275
1983	4863	4388	4273	4302	5208	6424	7316	7562	7649	7566	7173	6416	5848	5954	6095
1984	5721	5400	5494	6392	7313	8209	8577	8310	8257	7902	7299	6334	7383	6654	7101
1985	5407	4988	4891	5180	6885	7723	8065	8274	8291	8195	7741	6967	6836	6698	6884
1986	6344	6093	5777	6132	6570	7105	7037	6519	6392	6126	5439	4839	6523	7272	6198
1987	4260	3758	3629	3300	3946	4449	4762	4776	4800	4670	4169	3782	4144	5136	4192
1988	3606	3750	4012	4664	5990	6425	6676	6648	6652	6494	6214	5876	5736	4130	5584
1989	5333	5022	5092	5546	5926	6371	6639	6448	6414	6208	5831	5131	6004	5932	5830
1990	4507	4238	4202	4504	4958	5394	5449	5320	5228	5085	4598	3946	4971	5388	4786
1991	3401	3284	3376	3376	3875	4645	4858	4746	4654	4500	4203	3776	4146	4257	4058
1992	3330	3043	2997	3275	3929	4596	4979	4927	4845	4770	4502	4141	4117	3918	4111
1993	3765	3511	3402	3747	3639	4016	4196	3853	3722	3596	3395	3190	3809	4256	3669
1994	3096	3186	3549	4392	7543	8882	9327	9108	8925	8646	8068	7263	7134	3364	6832
1995	6530	6027	5739	6468	8900	9476	9440	9397	9205	8850	8164	7143	8237	7577	7945
1996	6318	5683	5308	5528	6367	7184	7692	7611	7504	7220	6674	5913	6615	7561	6584
1997	5259	4701	4337	4335	5111	6282	6799	6563	6337	6004	5390	4777	5571	6212	5491
1998	4229	3974	3871	4201	4507									5119	
Average	5113	4776	4691	5053	5979	6790	7064	6932	6796	6575	6145	5550	6085	5806	5955
Max.	7674	7458	7352	7137	8900	9680	9550	9397	9205	8850	8360	7758	8462	7873	8111
Min.	3096	3043	2997	3275	3639	4016	4196	3853	3722	3596	3395	3190	3809	3364	3669

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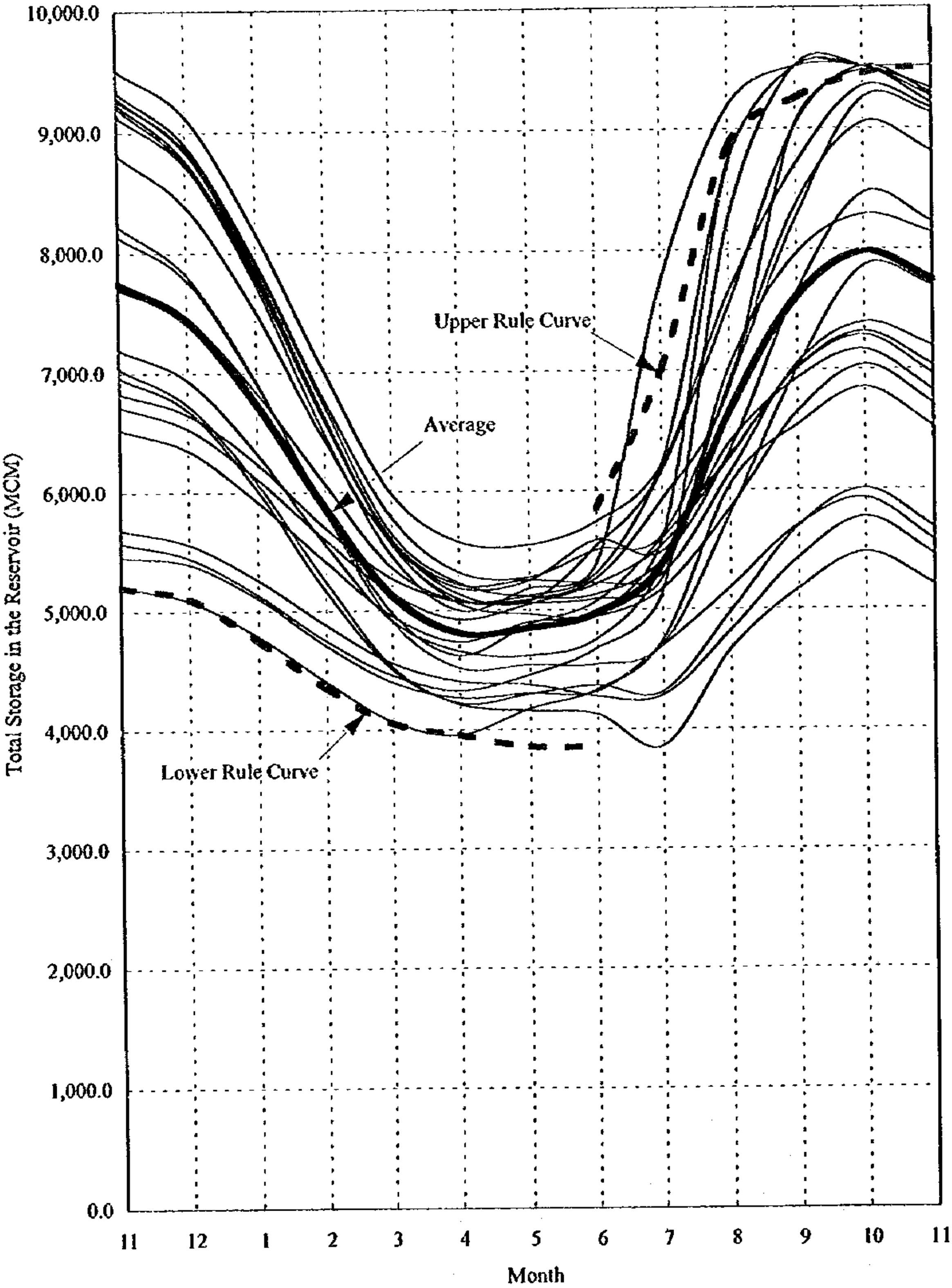
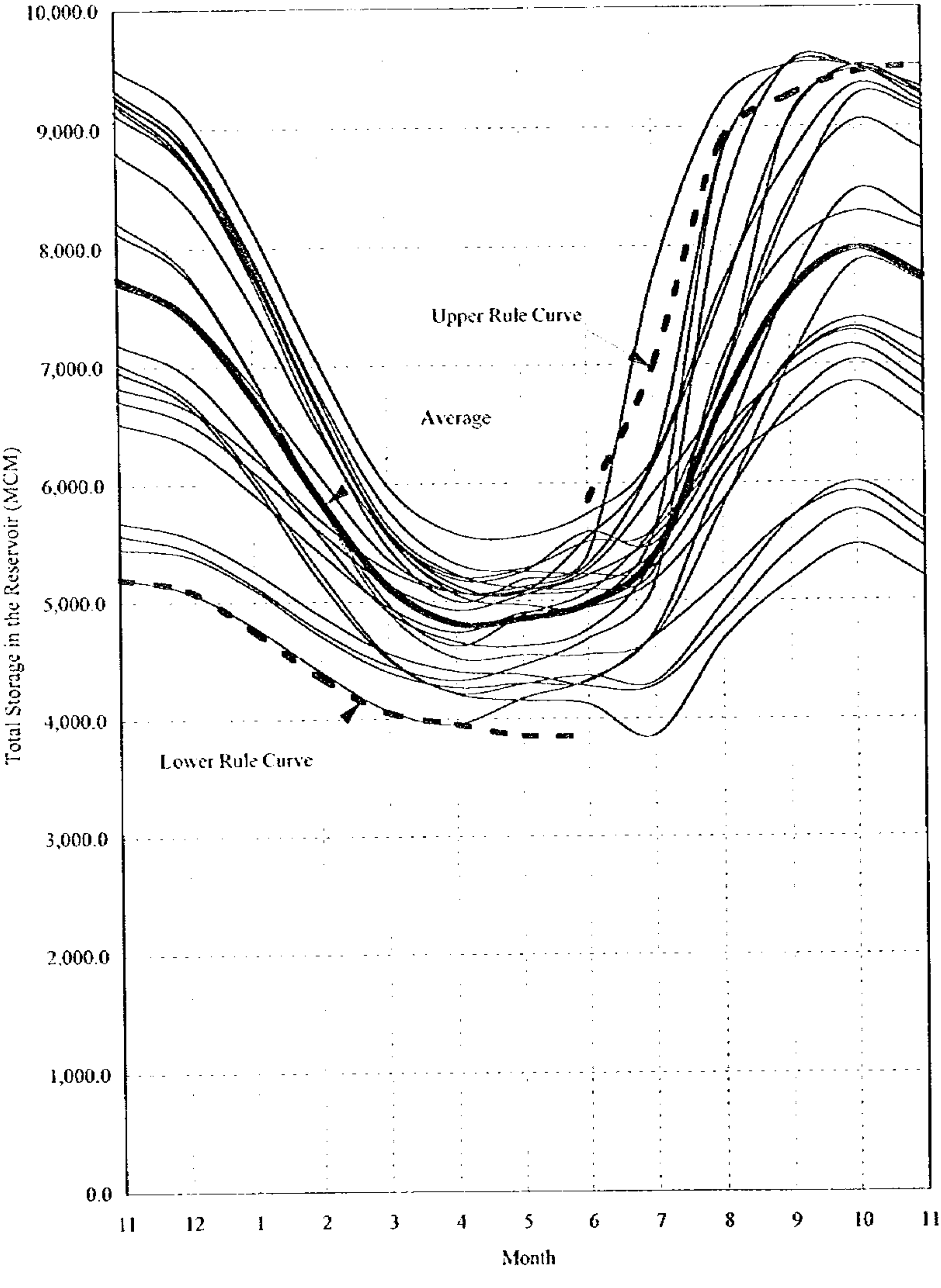
Figure 7.4.2 Sample Operation of the Sirikit Reservoir(1)



Higu PLOT2

Figure 7.4.2 Sample Operation of the Sirikit Reservoir(1)



Bgu PLOT2

Figure 7.4.3 Sample Operation of the Sirikit Reservoir(2)

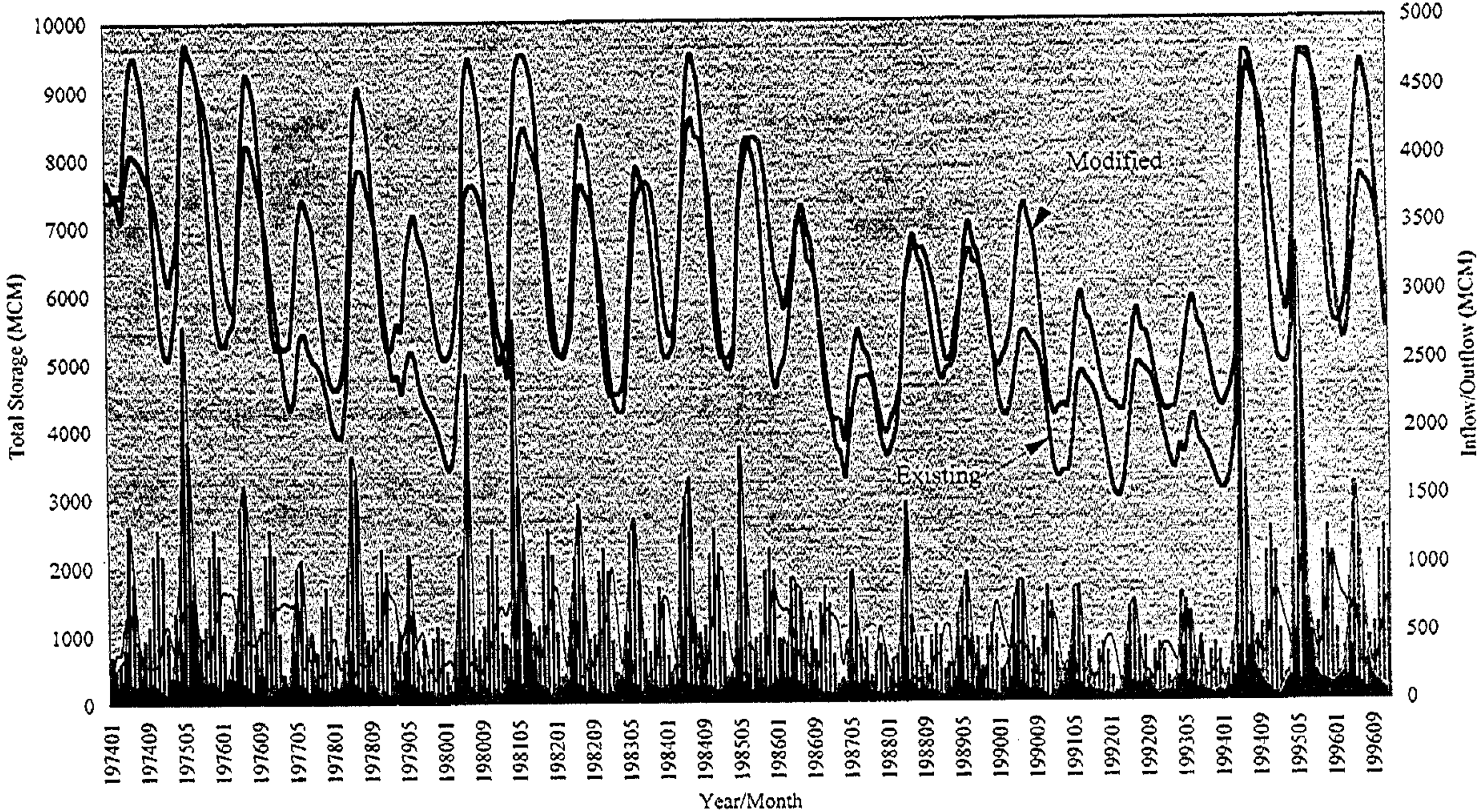


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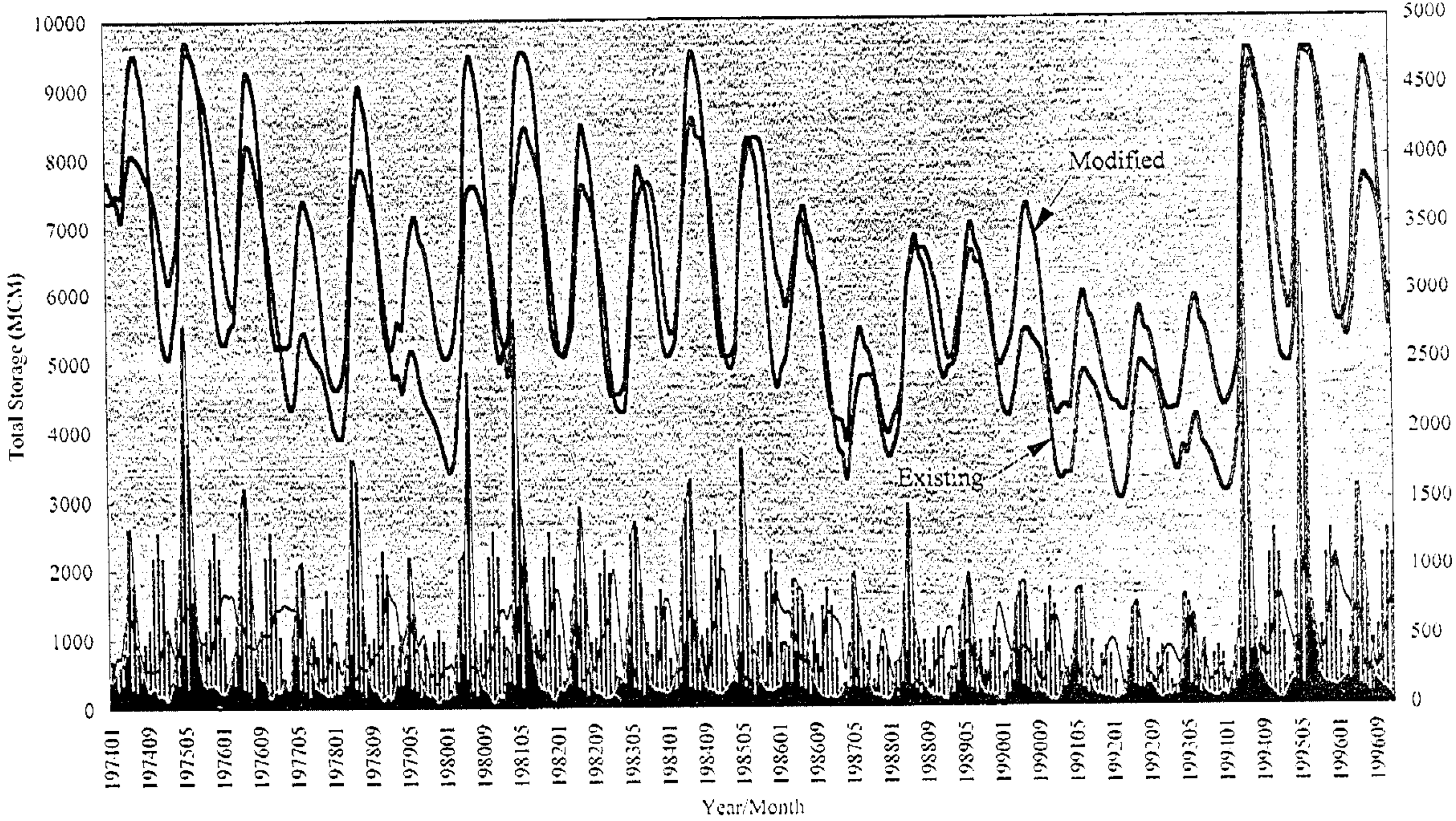
Figure 7.4.3 Sample Operation of the Sirikit Reservoir(2)



CHAPTER 8.

PROJECT WATER DIVERSION PLAN

CHAPTER 8. PROJECT WATER DIVERSION PLAN

8.1 Concept of Kok-Ing-Nan Water Diversion Plan

Shortage of water for various water user sectors including irrigated agriculture has been aggravated especially in the lower Chao Phraya basin as the result of rapid economic development activities in recent years. Strong environmental movement in these period to offer resistance against construction of any proposed large/medium scale storage dams has prompted RID to search a better alternative of transbasin diversion scheme.

The proposed Kok-Ing-Nan water diversion project is one of the optional plans which intend to divert surplus water in wet season transbasin from the river basin where water is abundant to the one where it is needed. The plan as envisaged would first divert the water from the Kok river at the existing Chiang Rai weir constructed by DEDP near the city of Chiang Rai. The use of the existing weir would minimize the environmental impact to be induced by the proposed scheme in the upper Kok basin, since no further construction of storage type structure is required. The diverted water would then be transported under gravity to the head of the Nan river basin through a series of channel and tunnel systems to meet the requirement of water in the lower Nan basin as well as in the Chao Phraya Delta area after once stored and regulated in the Sirikit reservoir. The diversion channel and tunnel will on the way intercept the runoff from the Ing river, and will supply water for irrigation and domestic uses in the Kok, Ing and upper Nan basins.

The proposed transbasin water diversion scheme primarily comprises the following three components;

- Kok to Ing diversion scheme,
- Ing to Nan diversion scheme, and
- Associated development schemes in Kok, Ing and upper Nan basins

Kok-Ing Diversion Scheme

The water diverted form the Kok river will be conveyed to the proposed diversion damsite on the Ing river near Amphoe Thoeng through a 50 km long diversion channel, composed of open canal, siphon, culvert and tunnel sections as required by topographic, geographical and present land use conditions. About 1,290 MCM/year of water will be diverted from the Kok river and transported through the diversion channel during wet season from June to December. The diversion channel will carry dry season water from the Kok river for the purposes of agricultural and other regional development within the Kok and Ing river basins, however the proposed scheme does not intend to carry any portion of water into the head of the Nan basin. The capacity of the Kok-Ing diversion channel is estimated at 140 cu.m/sec.

Ing-Nan Diversion Scheme

The above Kok-Ing diversion channel is linked with the Ing-Nan diversion channel at the proposed Ing diversion dam, where the waters from the Kok river and the Ing runoff combine.The scheme will divert the Ing water with the first priority, in order to minimize the capacity of the Kok-Ing diversion channel. Since the alignment of the Ing-Nan diversion channel passes unavoidably a rugged mountainous region, the Ing-Nan diversion channel is composed mostly of tunnel sections. The total length of the tunnel is estimated at some 50 km, with a discharge capacity of 175 cu.m/sec. The channel will carry about 2,090 MCM/year of water under gravity system, including 1,290 MCM from the Kok river and 800 MCM of the Ing runoff.

Associated Development Schemes in Kok, Ing and Upper Nan Basins

The proposed Kok-Ing-Nan water diversion project intends to first utilize the existing available runoffs of the Kok and Ing rivers for irrigated agriculture and other water resources development in the Kok, Ing and upper Nan basins. After utilizing the river flow for potential maximum water use within the basins probable in eventual future, the surplus or remaining flows in the river systems can only be the potential sources of water for the proposed Kok-Ing-Nan water diversion project. The study covers the identification of such potential developments, even though on a desk study level, to find out how much water should be reserved in the basins for future maximum water use.

8.2 Surplus Water in Kok and Ing Basins Available for Water Diversion

8.2.1 Definition of Surplus Water Resources Available in Kok and Ing Basins

In due consideration of rules for regional development and conservation of natural resources including land and water to be regulated by the new Constitution of Thailand as well as of the requests for further consideration to the JICA Study from various responsible governmental organizations such as MOAC, NESDB, MOSTE, the following basic concepts came to be realized.

The proposed Kok-Ing-Nan (KIN) Project envisages to divert the surplus water transbasin from the Kok and Ing basins to the Chao Phraya basin only during wet season. Definition of the surplus water resources is in principle to reserve the water resources to be responsible for potential water demand as assumed in eventual future in the Kok and Ing basins. In order to promote peoples' participation to the proposed KIN Project and also to cope with public relation purposes, it is therefore required to clarify the maximum potential of water resources development in the Kok and Ing basins and to provide sufficient information regarding this open to the public.

Surplus Water Available for the Proposed Water Diversion Plan
= Potential Surface Water Resources in the Kok and Ing Basins
- Existing Water Uses for Agriculture, Domestic and Other Purposes
- Water Necessary for Proposed Water Resources Development
- Water to be Reserved for Potential Development in Eventual Future
- Water Necessary for Downstream River Maintenance
- 5% of Special Allowance

(1) Maximum Development Potential in Kok and Ing Basins

1) Target year : none (eventual)
2) Irrigation service boundaries have to be shown on 1/50,000 maps, including;
   - Existing projects by all governmental agencies concerned,
   - Proposed projects already studied by all agencies concerned, and
   - Potential projects

     After indicating the service boundaries of existing and proposed projects on the maps, there remain rain-fed farmlands which will be discussed at a desk-study level to identify development potential taking into account the available water resources and possible irrigation layouts. It may be noted that every kind of effort should be made to minimize the rain-fed farmlands so that the potential projects could be explained satisfactorily to the people in the Kok and Ing basins.
3) Other Water Uses

   The water demand would be quite less than that for irrigation, however, this should be clearly spelled out (Att. Ecological or river maintenance flow).

(2) Water Demand in Kok and Ing Basin

Future water demand is to be estimated within a sufficient accuracy on the basis of information obtainable from RID, DEDP, PWA, ARD, etc. as well as of the forecasting of river maintenance flow downstream of the proposed intake point. Division of the river basin into sub-basins follows the guideline given by NESDB's 25 Basin Study. Thus dividing the Kok basin into 5 sub-basins and the Ing basin into 5 sub-basins, the data collected mainly from the results of Thai-side study were reviewed and sent to relevant agencies for confirmation.

In this connection in the Chao Phraya basin involving the upper and lower Nan basins, the proposed potential projects for water resources development by the target year 2016 is considered. In the upper Nan basin, the water resources available within its basin will be utilized in advance before flowing into the Sirikit reservoir and/or the water to be diverted transbasin from the Kok and Ing will be utilized for compensation purpose.

(3) Water Balance and Water Operation Period

The HEC-3 Model is used for water balance simulation undertaken to compare river flow conditions before and after the full potential development of water resources in the Kok and Ing basins.

The previous water operation period in the Conceptual Planning Study covered 20-year period from 1974 (April, 1974) to 1993 (March, 1994). This period is to be extended to cover a specific flood year of 1995, thus study period includes 23 years from April, 1974 up to March, 1997.

8.2.2 Potential Land and Water Resources in Kok and Ing Basins

(1) Potential Land Resources for Irrigation Development

The land use data obtainable from DLD show that there extends about 2,053,100 rai of agricultural land in Kok basin and about 1,807,600 rai in Ing basin including areas for slash-and-burn cultivation. The slash-and-burn cultivation areas, accounting for 37.5% and 2.6% of the total agricultural land respectively in Kok and Ing basins, are unavoidable to be restricted for conservation purposes in future, and therefore they are not a target for irrigation development. Of the total potential agricultural land for irrigation development, namely some 1,287,700 rai in Kok basin and 1,760,700 rai in Ing basin, paddy occupies about 64% and 74% while mixed field crops share 34% and 16% respectively in Kok and Ing basins.

Table 8.2.1 Agricultural Area Extended in Kok and Ing Basins

Agricultural Land Use	Kok Basin			Ing Basin		
	Area (rai)	Rate		Area (rai)	Rate	
		(n)/a	(n)/b		(n)/a	(n)/b
(1) Paddy Rice	820,478	63.7	40.0	1,309,487	74.4	72.4
(2) Mixed Field Crops	435,397	33.8	21.2	281,373	16.0	15.6
(3) Corn	-	-	-	160,357	9.1	8.9
(4) Mixed Tree Crops	-	-	-	9,528	0.5	0.5
(5) Mixed Orchards	31,808	2.5	1.5	-	-	-
Sub-total (a)	1,287,683	100.0		1,760,745	100.0	
(6) Rotating Field Crops	765,407		37.3	46,845		2.6
Total (b)	2,053,090		100.0	1,807,590		100.0

Source: DLD land use maps of 1/100,000 scale.

(2) Potential Water Resources

Assessment of potential surface water resources was made on the basis of data/records available from existing river gauging stations which are operated by RID and DEDP. The potential surface water resources so estimated within the basins are as follows;

Table 8.2.2 Potential Surface Water Resources

Basin	Location	Catchment (km^2)	Potential Surface Water Resources (MCM)				Remarks
			Annual	Yield (mm)	Wet	Dry	
Kok	Kok Intake	6,220	3,646	586	2,785	801	1972-92
Ing	Ing Intake	4,400	1,382	314	1,268	109	1968-96

Note: Annual April to May, wet season June to November, dry season December to May.

8.2.3 Water Demand Projection for Irrigation

(1) Existing Irrigation Development and Water Demand

Kok Basin

Having the Mae Lao Weir Project as the representative irrigation development of a large scale in the basin, at present 7 large/medium scale projects have been under operation with the irrigation service area of 119,200 rai and the irrigation intensity of 110%. Various types of medium scale projects and small scale projects including king's projects and peoples' projects are also under operation in the basin with the total service area of 320,700 rai. In addition to these, DEDP's pump irrigation projects are being operated with the service area of 24,100 rai. Such existing irrigation developments totalling up to 464,000 rai with an overall irrigation intensity of 110% have been consuming 440.5 MCM of annual amount of water which can be divided into 371.2 MCM in wet season and 69.3 MCM in dry season. About 122,700 rai of farmland which locates in Ing basin forming a part of the Mae Lao Irrigation Project are irrigated by water distributed transbasin from the Lao (Kok) sub-basin.

Ing Basin

At present 7 large/medium scale projects including a part of the Mae Lao irrigation project have been under operation with the irrigation service area of 252,700 rai and the irrigation intensity of 124% in the Ing basin. There are 33 medium scale irrigation package projects currently under operation with a total commanded area of 224,200 rai consuming irrigation water of 213.1 MCM/year. Various types of small scale projects are also under operation in the basin with the total service area of 206,500 rai. In addition to these, DEDP pump irrigation projects are being operated with the service area of 30,100 rai. Such existing irrigation developments have been consuming 730.8 MCM of annual amount of water which can be divided into 570.1 MCM in wet season and 160.7 MCM in dry season.

(2) Proposed Irrigation Development and Water Demand

Kok Basin

In the Kok basin, in total 9 projects, including the Chiang Rai Weir project under construction by DEDP, have been proposed for future implementation. Under the medium scale irrigation package projects, small scale projects and DEDP's pump irrigation projects, 428,000 rai of farm land with irrigation intensity of 110% will be covered in future by the year 2016. These projects will cover additional irrigation service areas of 249,200 rai in wet season and 47,700 rai in dry season distributing additional 270.9 MCM of annual volume of water for irrigation. Some of water developed in the Lao sub-basin by the proposed Mae Chadee, Mae Pun Luang, Mae

Yang Min and Mae Suai reservoirs will be reserved for uses as the potential development in the irrigated service areas in Ing basin.

Table 8.2.3 Proposed Large/Medium Scale Irrigation Development in Kok Basin

Proposed Project	Irrigation Area (rai)			Water Demand (MCM)		
	Wet	Dry	Total	Wet	Dry	Total
Fang Sub-basin						
Upper Fang Reservoir	18,100	5,400	23,500	14.5	8.1	22.6
Mae Thalop Luang Reservoir	9,300	2,800	12,100	7.4	4.2	11.6
Mae Na Wang Reservoir	13,000	3,900	16,900	10.4	5.9	16.3
Huai Khrai Reservoir	28,000	8,400	36,400	22.4	12.6	35.0
Kok-Lao Sub-basin						
Mae Chadee Reservoir	21,900	6,600	28,500	17.5	9.9	27.4
	(14,100)	(4,200)	(18,300)	(11.3)	(6.3)	(17.6)
Mae Pun Luang Reservoir	15,000	4,500	19,500	12.0	6.8	18.8
	(40,000)	(12,000)	(52,000)	(32.0)	(18.0)	(50.0)
Mae Yang Min Reservoir	(39,000)	(11,700)	(50,700)	(31.2)	(17.6)	(48.8)
Mae Suai Reservoir	1,120	450	1,570	4.9	4.5	9.4
	(62,500)	(18,800)	(81,300)	(50.0)	(28.1)	(78.1)
Middle, Lower Kok Sub-basin						
Chiang Rai Weir	48,700	4,900	53,600	39.0	7.4	46.3
Nong Luang	5,000	500	5,500	4.0	0.8	4.8
Kok-Ing Diversion	(34,800)	(17,400)	(52,200)	(27.8)	(26.1)	(53.9)

Note:Parenthesis denotes water transfer from Kok basin to Ing basin.

Table 8.2.4 Proposed Large/Medium Irrigation Development in Ing Basin

Proposed Project	Irrigation Area (ha)			Water Demand (MCM)		
	Wet	Dry	Total	Wet	Dry	Total
Upper Ing Sub-basin						
Nong Leng Sai	10,000	1,000	11,000	8.0	1.5	9.5
Mae Chai Reservoir	2,800	800	3,600	2.2	1.2	3.4
Rong Chang Reservoir	1,900	600	2,500	1.5	0.9	2.4
Middle Ing Sub-basin						
Lower Thoeng Weir	37,000	3,700	40,700	29.6	5.6	35.2
KIN Diversion (1)	(23,000)	(11,500)	(34,500)	(18.4)	(17.3)	(35.7)
Ing-Lao Sub-basin						
Nam Yuan Reservoir	20,000	6,000	26,000	16.0	9.0	25.0
Lower Ing Sub-basin						
Upper Thoeng Weir	12,000	1,200	13,200	9.6	1.8	11.4
Kin Diversion (2)	(11,800)	(5,900)	(17,700)	(9.4)	(8.9)	(18.3)
DEDP Pak-Ing Project	48,000	4,800	52,800	38.4	7.2	45.6

Note:Parenthesis denotes water transfer from Kok basin to Ing basin.

Ing Basin

In the Ing basin, in total 7 projects, including the Nam Yuan Reservoir project now under detail design work by RID, have been proposed for future implementation as shown in Table 8.2.4.

(3) Potential Irrigation Development and Water Demand

Service boundaries of both existing and proposed irrigation projects were plotted on the topo-maps of 1/100,000 scale. It is seen on the maps that there still remain large extent of agricultural land left rain-fed or undeveloped even after all of proposed developments have been implemented. In order to convert as much crop area as possible to irrigated agricultural land, a preliminary study was conducted to find out the maximum potential water resources development in the basins. Because of limited water resources especially during dry season, wet season waters are to be stored in reservoirs for uses in dry season. The study is therefore to find out promising sites for reservoir construction. However, the purpose of this desk study made only on 1/100,000 maps without any field reconnaissance is not to recommend further implementation of additional project but to estimate the maximum potentials of water resources development in the basins, because that the maximum amount of water resources is to be reserved within the basins for possible development in future.

Some previous findings were referred to in the studies on "Water Resources Survey and Development Plans, Chiang Rai Province, Thailand" prepared by Electro Watt/Motor Columbus of Switzerland in 1972 and "Mae Kok Project Fang Basin" Prefeasibility Report prepared by Salzgitter Consult GMBH in May 1973 to select promising damsites in the basins. From the desk study, following damsites/Projects as listed in Table 8.2.5 were preliminarily selected;

Table 8.2.5 Potential Damsites/Projects in Kok Basin

Potential Project	Sub-basin	Drainage Area (km²)	Average Runoff (MCM)	Reservoir Capacity (MCM)	Irrigation Area (ha)		
					Wet	Dry	Total
Mae Mao Reservoir	Fang	128	79	60.0	37,500	15,000	52,500
Mae Chai Weir	Fang	60	37	-			
Mae Sao Reservoir	Fang	115	69	40.0	20,000	6,000	26,000
Mae Leang Luang Reservoir	Fang	20	12	9.0	8,000	2,400	10,400
Mae Ai reservoir	Fang	24	15	10.0	6,300	1,900	8,200
Huai Pong Reservoir	Lao	14	4	4.0	4,400	1,300	5,700
Mae Khao Reservoir	Lao	117	32	30.0	4,400	1,800	6,200
Mae Tam Luang Reservoir	Lao	143	33	28.0	(19,400)	(5,800)	(25,200)
Huai Pong Phak Lao Res.	Lao	27	8	8.0	(5,600)	(1,700)	(7,300)
Huai Hia Reservoir	Lao	22	6	5.0	1,600	600	2,200
Huai Mae Kham Kaeng Res.	Lao	35	10	10.0	1,600	600	2,200
Huai Mae Tha Chang Res.	Lao	100	30	15.0	(10,600)	(3,200)	(13,800)
Mae Phrik Reservoir	Lao	44	13	8.0	2,500	1,000	3,500
Wiang Nang Project	Lower			-	35,000	3,500	38,500
Mae Lao Extension (*2)	Upper			-	164,800	49,400	214,200

Note: Figures in parentheses denote irrigation areas belong to the Ing basin.
(*2) Irrigated by the water developed in the Mae Chadee, Mae Pun Luang, Mae Yang Min, Mae Suai and other reservoirs to be constructed in the Lao sub-basin.

By means of constructing additional 13 reservoirs shown above, 330,900 rai of agricultural land may possibly be irrigated inclusive of the Mae Lao Extension area where waters are supplied from a number of storage reservoirs to be constructed in the Lao sub-basin through the extended Mae Lao irrigation canal. A comparison study of the existing, proposed and potential irrigation development in the Kok and Ing basins would result the followings;

Kok Basin

- Existing irrigation development covers 36% of agricultural area when slash-and-burn cultivation areas are ignored and 45% of practically irrigable area,
- Proposed development will cover 55% of agricultural area excluding slash-and-burn area and 70% of practically irrigable area, and
- Maximum potential development would cover 71% of agricultural area and 89% of practically irrigable area.

Ing Basin

- Existing irrigation development covers 41% of both agricultural area when slash-and-burn cultivation areas are ignored and practically irrigable area,
- Proposed development will cover 58% of both agricultural area excluding slash-and-burn area and practically irrigable area, and
- Maximum potential development would cover 68% of both agricultural area and practically irrigable area.

Table 8.2.6 Existing, Proposed and Potential Development in Kok and Ing Basins

Items	Kok Basin			Ing Basin		
	Area (rai)	Rate (%)		Area (rai)	Rate (%)	
		(1)/(2)	(1)/(3)		(1)/(2)	(1)/(3)
1. Agricultural Area by DLD						
(1) Paddy	820,478	40.0	63.7	1,309,487	72.4	74.4
(2) Mixed Field Crops	435,397	21.2	33.8	281,373	15.6	16.0
(3) Corn	-	-	-	160,357	8.9	9.1
(4) Sugarcane	-	-	-	-	-	-
(5) Cassava	-	-	-	-	-	-
(6) Legumes	-	-	-	-	-	-
(7) Mixed Tree Crops	-	-	-	9,528	0.5	0.5
(8) Mixed Orchards	31,808	1.5	2.5	-	-	-
(9) Rotating Field Crops	765,407	37.3	-	46,845	2.6	-
Sub-total Agricultural Area (1)	2,053,090	100.0		1,807,590	100.0	
2. Agricultural Area Excluding Rotating Field Crops (2)	1,287,683		100.0	1,760,745		100.0
3. Practically Irrigated Area *1(3)	1,022,500			1,754,000		
4. Existing Irrigation Development						
Development Area in Rai (4)	464,000			712,600		
Rate of Development (4)/(2)	36.0%			40.5%		
Rate of Development (4)/(3)	45.4%			40.6%		
5. Proposed Irrigation Development						
Development Area in Rai (5)	713,200			1,010,000		
Rate of Development (5)/(2)	55.4%			57.4%		
Rate of Development (5)/(3)	69.8%			57.6%		
6. Potential Irrigation Development						
Development Area in Rai (6)	907,700			1,187,300		
Rate of Development (6)/(2)	70.5%			67.4%		
Rate of Development (6)/(3)	88.8%			67.7%		

Note: (*1) The boundary of practically irrigable area of the basin was fixed on the 1/50,000 scale maps taking into account the topographic and other conditions and then measured by a planimeter.

(2) Areal extent of SSIP at the maximum development stage was assumed to be 200% of the existing achievement.

(3) That for DEDP pump irrigation project was assumed to be 150% of the existing achievement.

The results of such inventory surveys are presented in Tables 8.2.7 and 8.2.8. Locations of the potential sites of dams/reservoirs together with service boundaries of irrigated agriculture development are presented on the inventory maps which are compiled in the Supporting Database Maps.

8.2.4 Water Demand Projection for Others

Water demand projection for water use sectors other than irrigation made during the course of the Stage 1 Field Survey of the Phase 2 Study gives the projected water demand for each sector in 2046 and 2096. The study assumed that the domestic water consumer demand would increase from the 2046-2096 year level to eventual future under the anticipated lowest population growth, on the other hand the water supply efficiencies would be possibly improved due to adequate future investment and technology development. With an assumption that an increase of the water consumer demand in far future could be off-set by the improvement of water supply efficiencies, it may be judged that the 2046-96 year level demand would be deemed as approximate maximum potential water demand for domestic use. As regards the industrial water use, it was also assumed that the demand would be increased in response to the GBP growth from the 2046 year level to eventual future, however, the general tendency in advanced economic development indicates that an increase of industrial water demand would not appear due to the water saving effort and recycling, and the figures in 2046 year level would be deemed as a close proximity to the maximum potential water demand for industry use, taking this tendency into account. The study is summarized as follows;

Table 8.2.9 Water Demand for Other Uses (Surface Water) (Unit: MCM/year)

Sub-basin	Domestic Demand	Industrial Demand	Livestock Demand	Total Demand Other than Irrigation
Kok	75.09	16.01	1.75	92.85
Ing	87.90	2.97	2.28	93.15

8.2.5 Surplus Water Available for Water Diversion

Discharges of the Kok and Ing rivers at the proposed sites of the proposed water diversion are used primarily to irrigate the existing, proposed and potential agricultural areas, to supply domestic and other purposes within the basins and to maintain downstream river courses. Residual river flows after such water diversions are the potential source of water for the proposed water diversion project. As an allowance, 5% of water is subtracted from the residual river flow for future unforeseen water resources development in the basins.

Based on the results of the inventory survey which covers the existing, proposed and maximum potential development of water resources, schematic diagrams of the Kok and Ing river systems were prepared as shown in Figures 8.2.1 and 8.2.2. Based on the schematic diagrams, the water balance simulation was undertaken by employing the HEC-3 Model. The results from the water balance simulation are then summarized as below;

Kok River

Since the proposed project intends not to utilize the Lao (Kok) runoff from engineering point of view, evaluation of the Lao runoff is excluded from the water diversion planning study.

Table 8.2.10 Monthly Runoff of Kok River at Proposed Diversion Site (Existing, Unit=MCM)

	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Year
Mean	86	130	207	404	728	733	516	356	241	179	118	97	3,796
Max.	149	295	357	805	1,498	1,077	798	664	431	287	190	160	5,920
Min.	16	24	87	121	258	415	324	141	86	56	34	17	2,031

Table 8.2.11 Monthly Runoff of Kok River (After Potential Development, Unit=MCM)

	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Year
Mean	61	91	131	296	568	605	373	277	183	126	91	83	2,884
Max.	97	174	215	557	1,076	1,005	578	513	355	177	170	91	3,978
Min.	34	43	57	152	303	314	196	132	110	79	61	44	1,725

Ing River

The Lao (Ing) runoff was also excluded from the water diversion planning study during the course of the current study because of engineering and environmental points of view. The flows in the Ing river at the proposed site of water diversion before and after the potential developments are extracted from the results of water balance studies as follows;

Table 8.2.12 Monthly Runoff of Ing River at the Proposed Diversion Site (Existing, Unit=MCM)

	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Year
Mean	9	27	43	116	329	383	220	108	36	18	7	5	1,301
Max.	54	134	157	389	1,039	1,003	433	273	130	54	18	15	3,000
Min.	2	2	3	13	71	137	91	26	12	5	3	2	583

Table 8.2.13 Monthly Runoff of Ing River (After Potential Development, Unit=MCM)

	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Year
Mean	5	20	21	103	307	356	131	87	17	8	1	1	1,058
Max.	33	124	103	360	954	963	362	248	106	41	6	8	2,536
Min.	0	0	0	2	62	116	4	16	1	0	0	0	364

The surplus flow of the Kok and Ing rivers available for the proposed water diversion after withdrawal of necessary amount of water for the potential water resources development within the basins is tabulated as given in Tables 8.2.14 to 8.2.15 and Figures 8.2.3 to 8.2.4.

8.3 Optimum Diversion Capacity

8.3.1 Projected Role of Sirikit Reservoir

The proposed Kok-Ing-Nan Water Diversion Project aims at gaining as much increased storage in the Sirikit reservoir as possible at the end of wet season for promotion of downstream water release in the succeeding dry period and also providing as much increased storage space as possible at the end of dry season or beginning of wet season for unforeseen flood runoff from the catchment. These effects conflicting each other will be achieved only when the water diverted transbasin from Kok and Ing is introduced into the reservoir.

An ideal pattern of operation of the Sirikit reservoir is to restore its storage toward the full storage at the end of November using runoff during recovery period from July to November, and to utilize the storage during consumptive period from December to next May, in response to the request from downstream water users. In view of flood control, reservoir water level is also ideal to be the lowest at the end of June when flood runoff begins to flow into the reservoir. The selection of the optimum capacity of diversion canals and tunnels is therefore made in connection with the operation of the Sirikit reservoir, in order to maximize the efficiency of the reservoir storage.

8.3.2 Optimum Diversion Capacity

Possible amount of water diversion from the Kok and Ing basin to the Sirikit reservoir largely depends on the discharge capacity of diversion channel. A larger amount of water may be expected as the capacity enlarges, however the rate or incremental raise of amount may decrease when the capacity exceeds a certain limit. A greater construction cost will be required for a larger diversion channel and over-estimation may cause needless control of diversion when the reservoir is filled with runoff from its own catchment, and therefore be uneconomic.

The following combinations of diversion capacities were put into the comparative study;

Capacity of Kok-Ing Diversion Canal/Tunnel	75, 100, 125, 140, 165 m^3/sec
Capacity of Ing-Yot Diversion Tunnel	110, 135, 160, 175, 200 m^3/sec

The amounts of water which can be diverted from the Kok and Ing rivers and transferred to the Sirikit reservoir, operated under the present upper rule curve, through the Yot, Yao and Nan rivers for various diversion capacities are extracted from water balance simulation as shown in Figure 8.3.1 and as summarized in Table 8.3.1. The figure 8.3.1 revealed the fact that (1) the potential total amount of diversion increases as the capacity of Kok-Ing channel enlarges, however a growth rate of increase turns negligible if the capacity of Kok-Ing channel exceeds 140 m^3/sec, and (2) it also turns to decrease when the capacity of the Ing-Yot tunnel exceeds 175 m^3/sec.

Table 8.3.1 Amount of Water to be Diverted from Kok and Ing Rivers

Item		Capacity of Kok-Ing Diversion Canal/Tunnel (m^3/sec)				
		75	100	125	140	165
Capacity of Ing-Yot Diversion Tunnel (m^3/sec)	110	1,564	1,617	-	-	-
	135	1,696	1,793	1,832	-	-
	160	1,805	1,919	1,991	2,009	-
	175	1,852	1,975	2,066	2,094	2,097
	200	1,910	2,032	2,128	2,146	2,155

In order to evaluate the best suitable capacity of diversion canals and tunnels, the amounts of water to be effectively and safely diverted from the Kok and Ing rivers without wasted in the Sirikit reservoir through spillage (effective diversion) and the costs to be required for construction of canals/tunnels with various capacities were extracted from the above case studies of Sirikit reservoir operation as given in Table 8.3.2.

- Construction costs for the Kok intake, main office, Ing diversion weir, Yao flood control dam and Yao river training works are common for all alternative cases of diversion capacity.
- Construction costs for diversion canals and culverts vary depending on their capacities.
- Construction costs for tunnel works vary widely depending on alternative capacities, so that costs are assembled from breakdown of costs for excavation works, concrete works, temporary works, etc.

A combination of 140 cu.m/sec of diversion capacity for the Kok-Ing diversion canal /tunnel and 175 cu.m/sec for the Ing-Yot canal/tunnel showed the lowest investment cost as is seen in Table 8.3.2. Breakdown of construction costs is detailed in Tables 8.3.3 to 8.3.5.

The project benefits consisting of benefit from water supply, hydropower generation and irrigated agriculture are as follows;

Benefit for Water Supply

The volume of water to be allocated for municipal/domestic and industrial water supply, amounting to 825 MCM/dry season, is common for all alternative cases.

4.79 Baht/m3 x 825,000,000 m3 x 70% = 2,766 million Baht,
where water loss is estimated at 30% of raw water.

Benefit for Hydropower Generation

Benefit for hydropower generation is estimated based on the volume of water to be diverted for each alternative case, as follows;

Table 8.3.6 Benefit for Hydropower Generation

Alternative Capacity (m^3/s) Item	K=140 I=200	K=140 I=175	K=125 I=160	K=125 I=135	K=100 I=110
(1) Available Diversion Water (MCM)	2,416	2,094	1,991	1,832	1,617
(2) Additional Power Generated (Gwh)	314.5	306.9	291.8	268.5	237.0
(3) Opportunity Cost of Power (Baht/kwh)	1.12	1.12	1.12	1.12	1.12
(4) Power Benefit (10^6 Baht)	352.2	343.7	326.8	300.7	265.4

Agricultural Benefit

Agricultural benefit is estimated as shown in Table 8.3.7 taking into account available irrigation water, cropped area to be irrigated by available water and the unit benefit per rai.

Table 8.3.8 Benefit for Agriculture

Alternative Capacity (m^3/s) Item	K=140 I=200	K=140 I=175	K=125 I=160	K=125 I=135	K=100 I=110
(1) Available Diversion Water (MCM)	2,416	2,094	1,991	1,832	1,617
(2) Available Water for Irrigation (Gwh)	2,121	2,069	1,966	1,807	1,592
(3) Cropping Area (10^3 rai)	1,350	1,315	1,245	1,145	1,010
(4) Power Benefit (10^6 Baht)	10,750	10,447	9,926	9,123	7,990

Total Project Benefit

Total project benefit and the benefit/cost ratio is calculated as follows;

Table 8.3.9 Total Benefit

Alternative Capacity (m^3/s) Item	K=140 I=200	K=140 I=175	K=125 I=160	K=125 I=135	K=100 I=110
(1) Benefit - Water Supply (10^6 Baht)	2,776	2,776	2,776	2,776	2,776
Benefit - Hydropower (10^6 Baht)	352	344	327	301	265
Benefit - Agriculture (10^6 Baht)	10,750	10,447	9,926	9,123	7,990
Total Benefit	13,868	13,557	13,019	12,190	11,021
(2) Construction Cost (10^6 Baht)	33,554	32,220	31,100	30,077	28,383
(3) Benefit - Cost Ratio (1)/(2)	41.3%	42.1%	41.9%	40.5%	38.8%

Accordingly the following combination of diversion capacities was selected;

Table 8.3.10 Proposed Diversion Capacity

Diversion Channel	Capacity
Ing - Nan	175 cum/sec
Kok - Ing	140 cum/sec

Flow conditions of the Kok and Ing rivers before and after the proposed water diversion with the capacities of 140 cu.m/sec for the Kok-Ing diversion canals/tunnels and 175 cu.m/sec for the Ing-Yot canals/tunnels were then compared as shown in Figure 8.3.3 and 8.3.4.

Distribution of irrigable areas in sub-basins, on which water balance calculations were based, is given in Figure 8.3.5, while monthly pattern of water volume to be diverted from and the existing and residual flow after diversion of the Kok and Ing rivers are illustrated respectively in Figures 8.3.6 and 8.3.7.

8.4 Proposed Water Diversion Plan

8.4.1 Improved Operation Rule of Sirikit Reservoir

In consideration of seasonal pattern of rainfall in the irrigation service area as well as of available runoff flowing into the river from where water is diverted for irrigation and other purposes, the Sirikit water has a significant importance for dry season crops under vegetative and reproductive stages and under initial irrigation stage for wet season crops. In irrigated service area under such situations, it must be intolerable and irresistible that the water supply from the reservoir be interrupted. It is, therefore, inevitably necessary that the reservoir is so operated as to ensure its storage by this time. In planning a rational operation of the reservoir against more complicated requirement of water for irrigation and others, an objective standard must be necessarily required to be established.

During dry season, operation of reservoir is undertaken in a way that two purposes confronting each other can be adjusted. The first objective is to promote water release effectively in response to demand of the service area. However, as a result, promotion of water release accelerates consumption of available storage in the reservoir. Secondly, some countermeasures for unforeseen drought is needed. In preparation for present and future drought, water release is rather restricted intending preservation and restoration of storage. In accordance with the available storage in the reservoir at the beginning of dry season, the following plan of water release during dry season was tentatively set up;

Table 8.4.1 Water Release from the Reservoir during Dry Season

Month	Rate (%)	Active Storage Available at the End of November (MCM)				
		>6,000	6,000 to 5,000	5,000 to 4,000	4,000 to 3,000	<3,000
Dec.	12	840	720	624	504	444
Jan.	23	1,610	1,380	1,196	966	851
Feb.	27	1,890	1,620	1,404	1,134	999
Mar.	23	1,610	1,380	1,196	966	851
Apr.	11	770	660	572	462	407
May	4	280	240	208	168	148
Total	100	7,000	6,000	5,200	4,200	3,700

During wet season when inflow into the reservoir largely exceeds water demand under the normal condition, the reservoir should be so operated that i) as much water release as possible be allotted for power generation, ii) as small amount of water as possible be wasted through spillage, and iii) reservoir be finally recovered to the full storage level as frequent as possible at the end of wet season. Accordingly even during wet season, a role of reservoir operation is constructed by means of establishing various modes of allowable release with respect to available storage, aiming at the most effective utilization of the limited water resources for multiple purposes of irrigation, hydro-electric power generation and other water supplies.

In order to achieve the above objectives, following upper and lower rule curves for improved operation of the Sirikit reservoir under with Kok-Ing-Nan project condition were given;

Table 8.4.2 Upper Rule Curve of Reservoir Operation

Month	June	July	Aug.	Sep.	Oct.	Nov.
Storage (MCM)	1,300	2,900	5,000	6,000	6,500	6,660

Table 8.4.3 Lower Rule Curve of Reservoir Operation

Month	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Storage (MCM)	3,100	2,600	2,000	1,400	900	100	0

About 2,810 MCM of water could be released from the reservoir during dry season in addition to the present achievement of 2,800 MCM amounting to a total release of 5,610 MCM. About 1,460 MCM of flood control capacity will also be added to the present capacity of 4,800 MCM for unforeseen flood during wet season meaning that the proposed project would contribute to a great extent to flood control in the Nan river system. Deviations of flood control capacity from the mean annual value are also distributed within a range of ±500 MCM under the improved situation of reservoir operation. The results of reservoir operation study mentioned above are visualized as given in Figures 8.4.1 to 8.4.3.

Table 8.4.4 Comparative Table of Water Balance at Sirikit Reservoir (MCM)

	Existing Situation	Improved Situation	Increase
Dry Season Outflow	2,800	5,610	2,810
Flood Control Capacity	4,800	6,260	1,460
Power Generated, GWh	820	1,170	350

8.4.2 Flow Regime in Diversion Canals and Tunnels

The above-mentioned plan intends to divert about 1,250 MCM/year and 800 MCM/year of water during wet season respectively from the Kok and Ing rivers. Table 8.4.5 shows the frequency of discharges to be diverted from the Kok and Ing rivers as well as discharges passing through the Ing-Yot tunnel. It is noted here that the discharges diverted from the Kok river are distributed moderately throughout a wet season within a wide range between nearly zero to the maximum of 140 cu.m/sec, while the maximum discharges of intake, 175 cu.m/sec, from the Ing river concentrate only during two months, August and September. This phenomenon is visualized also in Figures 8.4.4 and 8.4.5.

Average monthly discharges to be diverted from both rivers and those passing through the Ing-Yot tunnel are extracted from the water balance computation as is seen in Figures 8.4.6 to 8.4.8 and as summarized under;

Table 8.4.6 Average Monthly Discharges of Water Diversion (Unit=cu.m/sec)

	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Diversion from Kok River	47.5	74.7	71.8	63.5	95.6	90.9	64.5
Diversion from Ing River	7.6	35.2	92.9	108.2	46.3	31.7	6.2
Discharge in Ing-Yot Tunnel	55.2	109.9	164.7	171.7	141.9	122.6	70.7

8.5 Additional Considerations on Further Possible Water Diversion

8.5.1 Influence of Water Diversion on the Flow Condition of the Mekong River

The proposed project intends to divert in total 2,008 MCM of water mainly from excess runoff of the Kok and Ing rivers in wet season from June to November, including 76 MCM of diversion in December when both rivers still maintain considerable amount of flow.

Table 8.5.1 Influence of Water Diversion on Mekong River

Period of Year	Proposed Water Diversion (1)	Mekong River			
		At Chieng Saen		At Chiang Khan	
		Runoff (2)	Rate (1)/(2)	Runoff (3)	Rate (1)/(3)
June to December	2,094	66,873	3.1%	112,082	1.9%
January to May	0	13,880	0.0%	17,288	0.0%
Total	2,094	80,753	2.6%	129,370	1.6%

(Unit: MCM)

From the above table, the proposed amount of water diversion shares 3.1% of original flow of Mekong river at Chieng Saen during the period from June to December and 2.5% of an annual total value. The proposed figures are also compared with Mekong's flow condition at Chiang Khan, showing 1.8% during June to December and 1.6% of an annual total. Since the Mekong river flows deep mountainous area in Laos and there are almost no existing or proposed water resources development in the area between Chieng Saen and Chiang Khan, it may be no objection to conclude that the proposed project would exert influence on the flow condition of Mekong river as small as less than 2%.

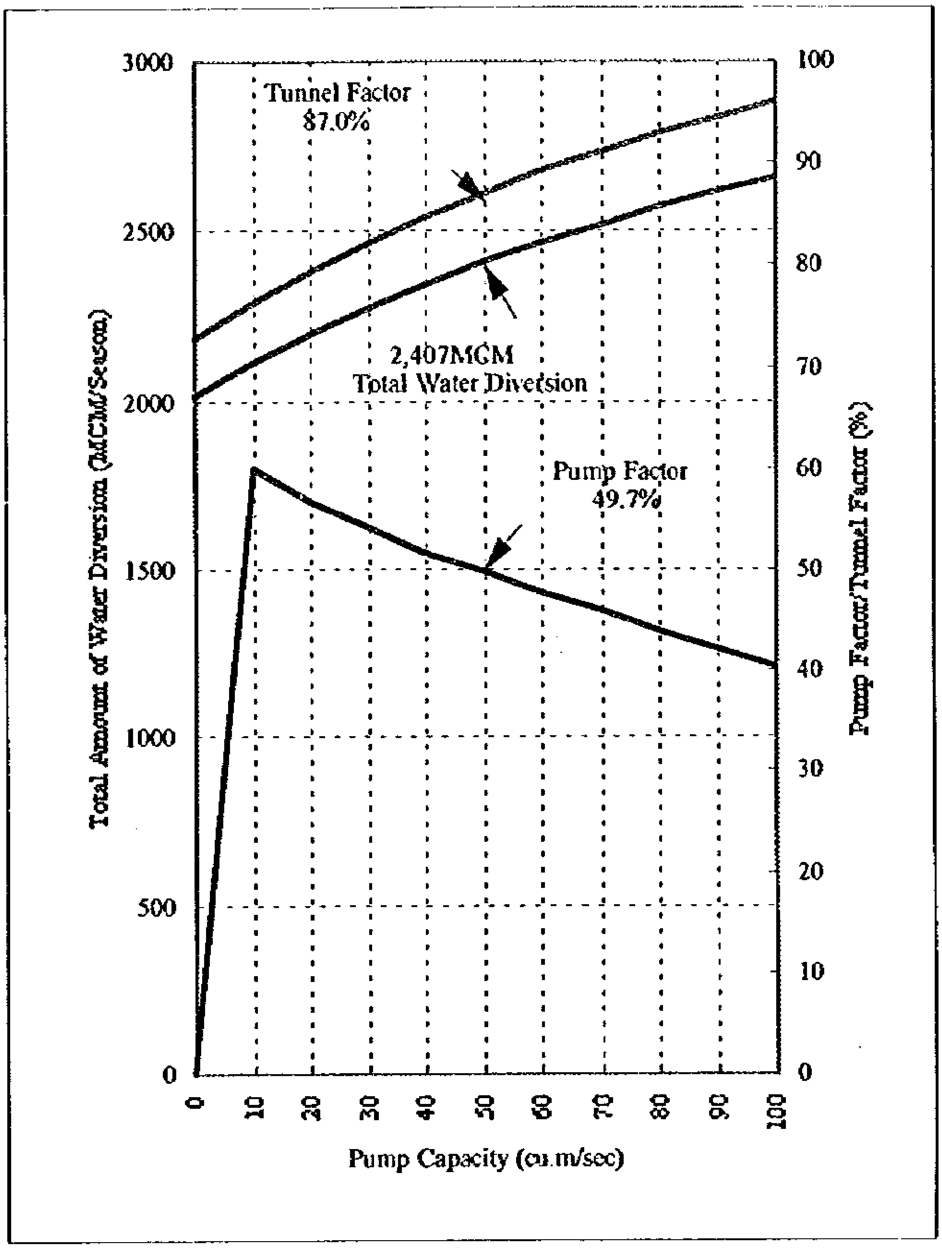
8.5.2 Possibility of Pumping Water Diversion from Lower Ing River

According to the analyses made for selection of suitable capacities of diversion canals and tunnels, the average annual volume of water to be diverted from the Kok and Ing rivers and then conveyed through the canals/tunnels is estimated at 2,094 MCM, showing a much smaller value when compared with its full capacity of 2,770 MCM (175 cu.m/sec x 183 days in wet season). This is due to the fact that the flows in the river system in June, July and November varying from 40 cu.m/sec to 110 cu.m/sec are more or less smaller than the canal/tunnel capacity, resulting that there are considerable empty spaces in the diversion channel.

Along the Ing river downstream of the proposed Ing diversion damsite, there are numbers of large and small tributaries, represented by the Nam Hong Khua and Nam Mae Tak, flowing into the Ing river supplying a plenty of excess flow especially during wet season. In addition, the river water level is used to reach 345 m to 350 m, MSL around the Ing river mouth affected by water level in the Mekong river. Such hydrological and hydraulic condition allows the Ing river water level to reach 360 m, MSL at the Ban Nam Ing, located at the confluence of the Nam Mae Tak with the Ing river about 20 km downstream of the Ing diversion dam. It is considered to be possible and easy to divert excess flows from the lower Ing river into the proposed diversion canals and tunnels in order to fill the empty capacity and to increase the total volume of diversion, if a rubber dam is constructed and a pumping station is installed at this point.

A preliminary study was undertaken to set up a suitable pumping capacity as shown in the figure. The study showed that the pumping capacity of 50 cum.m/sec would be suitable, indicating a pumping factor of 49.7%, tunnel factor of 87.0% and the total amount of diversion into the Sirikit reservoir would be about 2,400 MCM/year meaning that about 390 MCM of water could be diverted from the lower Ing basin.

Figure 8.5.1 Pumping Capacity and Total Amount of Water Diversion



In the above explanation, the pumping factor is defined in terms of a rate of the total volume of water to be pumped up against the full capacity of pumping for 24 hours during the concerning period from June to November, a tunnel factor is a rate of volume of water to be conducted through the diversion tunnel against the full capacity of 2,767 MCM, and the total amount of diversion is defined as the total volume of water come from the Kok and Ing rivers supplemented with water pumped up from the lower Ing river.

Table 8.5.2 Pumping Capacity, Pump Factor, Tunnel Factor and Total Diversion

Pumping Capacity (cu.m/sec)	Pump Factor (%)	Tunnel Factor (%)	Total Amount of Diversion (MCM/year)	Diversion by Pump (MCM/year)
0	0.0	72.8	2,014.2	0.0
10	60.0	76.2	2,109.1	94.9
20	56.6	79.3	2,193.2	179.0
30	54.0	82.1	2,270.3	256.1
40	51.6	84.6	2,340.3	326.1
50	49.7	87.0	2,407.3	393.1
60	47.8	89.2	2,467.2	453.0
70	45.8	91.1	2,521.6	507.4
80	44.0	92.9	2,571.3	557.1
90	42.2	94.5	2,614.5	600.3
100	40.3	95.8	2,651.9	637.7

Note: Water diversion in December is excluded from computation.

8.5.3 Possibility for Water Diversion Plan by Kok Hydropower Dam

The Mae Kok hydro-power dam is going to be constructed on the Kok river near the Myanmar territory. This hydropower dam plan was originally formulated by the Electric Power Development Company (E.P.D.C), Japan under the technical assistance to EGAT in 1992 and has a high possibility for implementation from technical and economic aspect, so that the JICA Team has collected relevant data and carried out the following preliminary study. Outline of the project is given preliminarily as under;

- Damsite Location, — Kok upstream in Myanmar territory 3 km far from the border of Thailand
- Reservoir Dimension
  - Drainage Area at Damsite — 2,980 km^2
  - Annual Inflow — 2,230 MCM
  - Full Water Level — 570 m, MSL
  - Low Water Level — 550 m, MSL
  - Gross Storage Capacity — 4,650 MCM
  - Effective Storage Capacity — 1,650 MCM
- Dam Dimension
  - Type — Concrete Dam
  - Crest Elevation — 575 m
  - River Bed Elevation — 450 m
  - Dam Height — 125 m
- Hydropower Outline
  - Maximum Outflow — 300 m^3/sec
  - Effective Power Head — 112 m
  - Installed Power Capacity — 290 MW
  - Annual Energy Production — 637 GWh

The annual average runoff of 2,200 MCM consisting of 200 to 400 MCM/month in wet season and 50 to 100 MCM/month in dry season will be completely regulated by the Mae Kok reservoir having a large effective capacity of 1,650 MCM. The reservoir will be operated as follows ;

- Out of average annual runoff of 2,200 MCM, the wet and dry season runoffs are 1,700 MCM and 500 MCM respectively.
- Out of 1,700 MCM in wet season runoff, 900 MCM will be used for hydropower generation in wet season without stored in the reservoir and the remaining 800 MCM will be used to restore storage for the use in dry season.
- Accordingly, the dry season outflow at the dam will reach as much as 1,300 MCM combining the dry season natural runoff of 500 MCM and the retained water of 800 MCM.
- Annual runoff generally shows a large fluctuation ranging from 3,000 MCM in a wet year to 1,300 MCM in a dry year. Therefore, the carry-over capacity of 600 to 700 MCM will be required in the reservoir at the end of dry season in order to cope with a lesser reservoir inflow in dry years. Namely, the capacity of 1,000 MCM out of the effective capacity of 1,650 MCM would be used for actual reservoir operation in the normal year.

Runoff of Kok river at the proposed damsite will change after controlled by the storage function of the reservoir, as a result, raising the dry season flow of Kok river at the site of the Kok diversion dam.

Table 8.5.3 Possible Change of Flow Condition at the Kok Diversion Dam

Items	Total	Wet Season			Dry Season		
		6-7	8-9	10-11	12-1	2-3	4-5
Present Runoff at the Kok Diversion Dam	3,800	610	1,450	880	420	220	220
Runoff from Catchment downstream of Kok dam	1,600	260	600	370	180	90	100
Outflow from Kok Dam	2,200	300	300	300	430	440	430
Changed Runoff at Kok Diversion Dam	3,800	560	900	670	610	530	530
Discharge Equivalent of Changed Runoff (m^3/sec)	120	106	170	127	114	104	101
Discharge Equivalent of Kok Outflow (m^3/sec)	70	57	57	57	82	86	82

As is clear in the above table, the runoff at the Kok diversion dam after the construction of Kok dam is mostly controlled and the average discharge is 100 to 120 m^3/sec throughout the year except the discharge of 170 cum./sec in August and September which is the flood months.

Accordingly the following volume of water could be diverted from the Kok river at the Kok diversion dam after construction of the Mae Kok hydro-power dam.

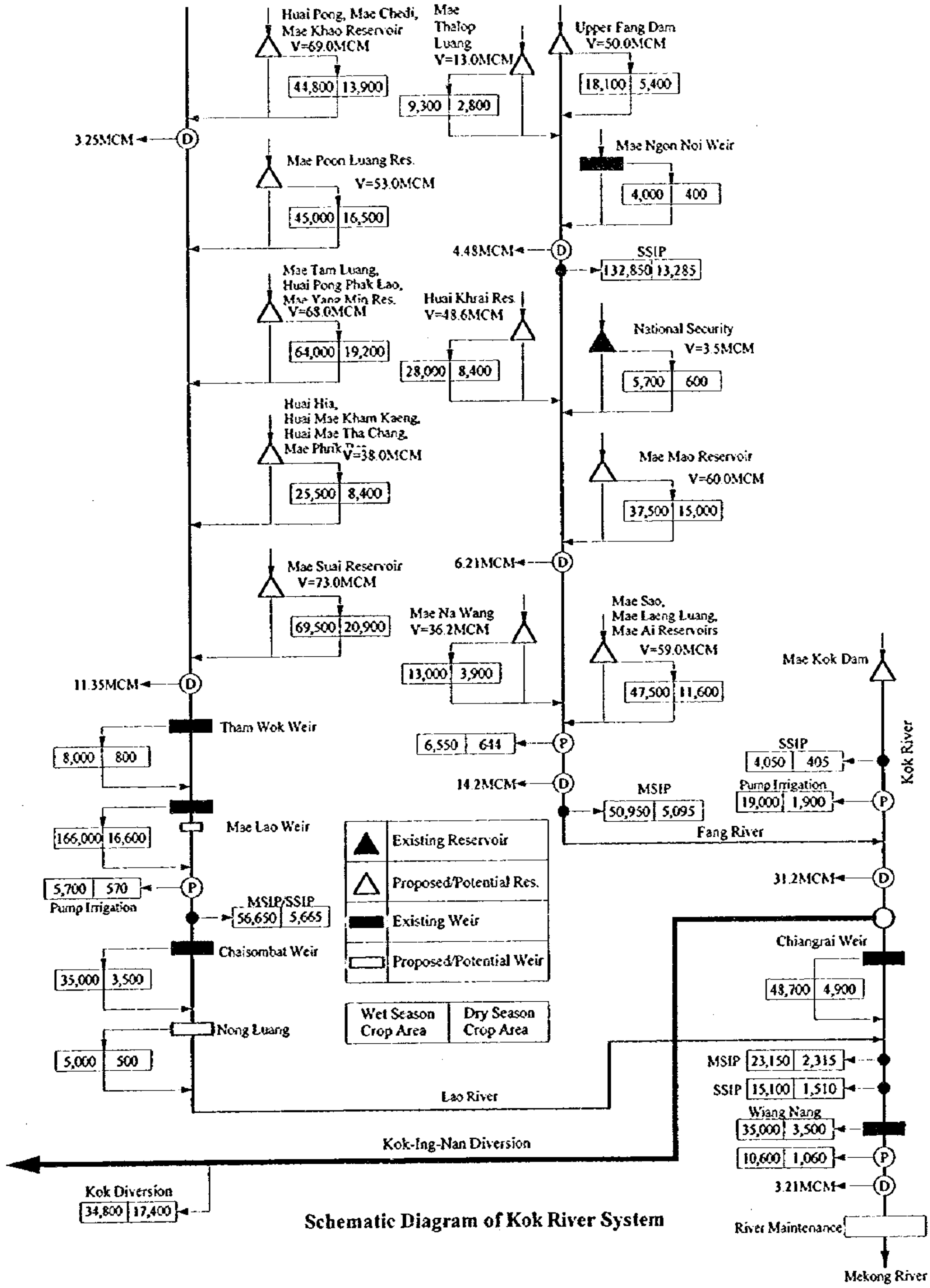
June and July	100 m^3/sec x 2 months x 70% =	370 MCM
August to September	140 m^3/sec x 2 months x 90% =	660 MCM
October and November	125 m^3/sec x 2 months x 70% =	460 MCM
Wet Season Subtotal		1,490 MCM

December and January	110 m³/sec x 2 months x 70% =	410 MCM
February to March	100 m³/sec x 2 months x 70% =	360 MCM
April to May	100 m³/sec x 2 months x 70% =	370 MCM
Dry Season Subtotal		1,140 MCM
Annual Total		2,630 MCM

The water to be diverted from the Kok river at the Kok diversion damsite will reach about 1,500 MCM level in wet season with the increase of about 300 MCM as compared with the case of 1,200 MCM without Kok hydropower dam, while the 1,140 MCM could be additionally diverted in dry season. The above increased additional water could be used as follows ;

- 300 MCM in wet season will be stored once in the Sirikit reservoir for use in dry season for irrigation and other purposes in the Chao Phraya basin located downstream of the Sirikit reservoir.
- Out of 1,140 MCM of additional water in dry season, some will be used for irrigation in the Kok and Ing basins and the remainder will be transported to the Chao Phraya basin through Sirikit dam.

Figure 8.2.1 Schematic Diagram of Kok River System



Schematic Diagram of Kok River System

Figure 8.2.2 Schematic Diagram of Ing River System

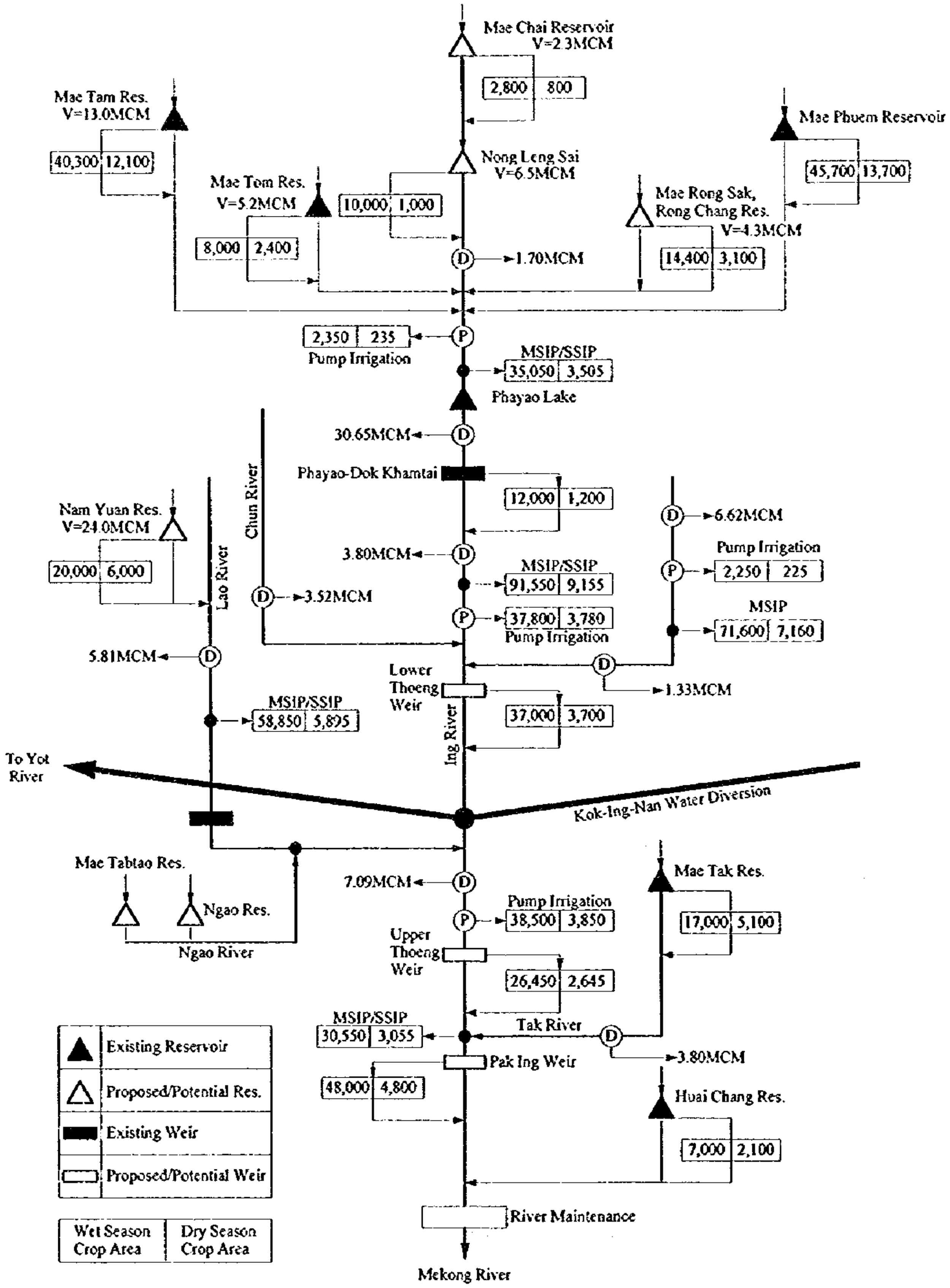


Figure 8.2.3 Kok River Flow before/after Potential Development

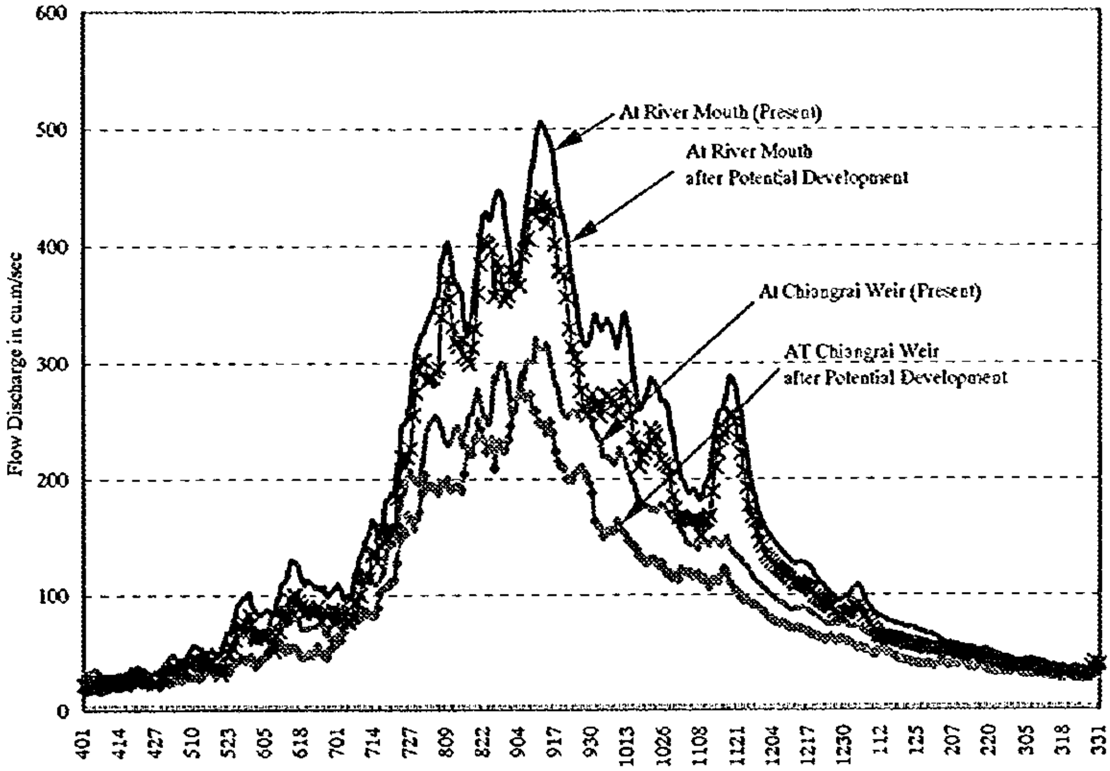


Figure 8.2.4 Ing River Flow before/after Potential Development