METROPOLITAN
WATER WORKS
AUTHORITY

โครงการประปาระบบอิสระ

FEASIBILITY STUDY FOR THE SEPARATE SYSTEM OF METROPOLITAN WATER SUPPLY IN BANGKOK, THAILAND

SUMMARY OF FINAL REPORT

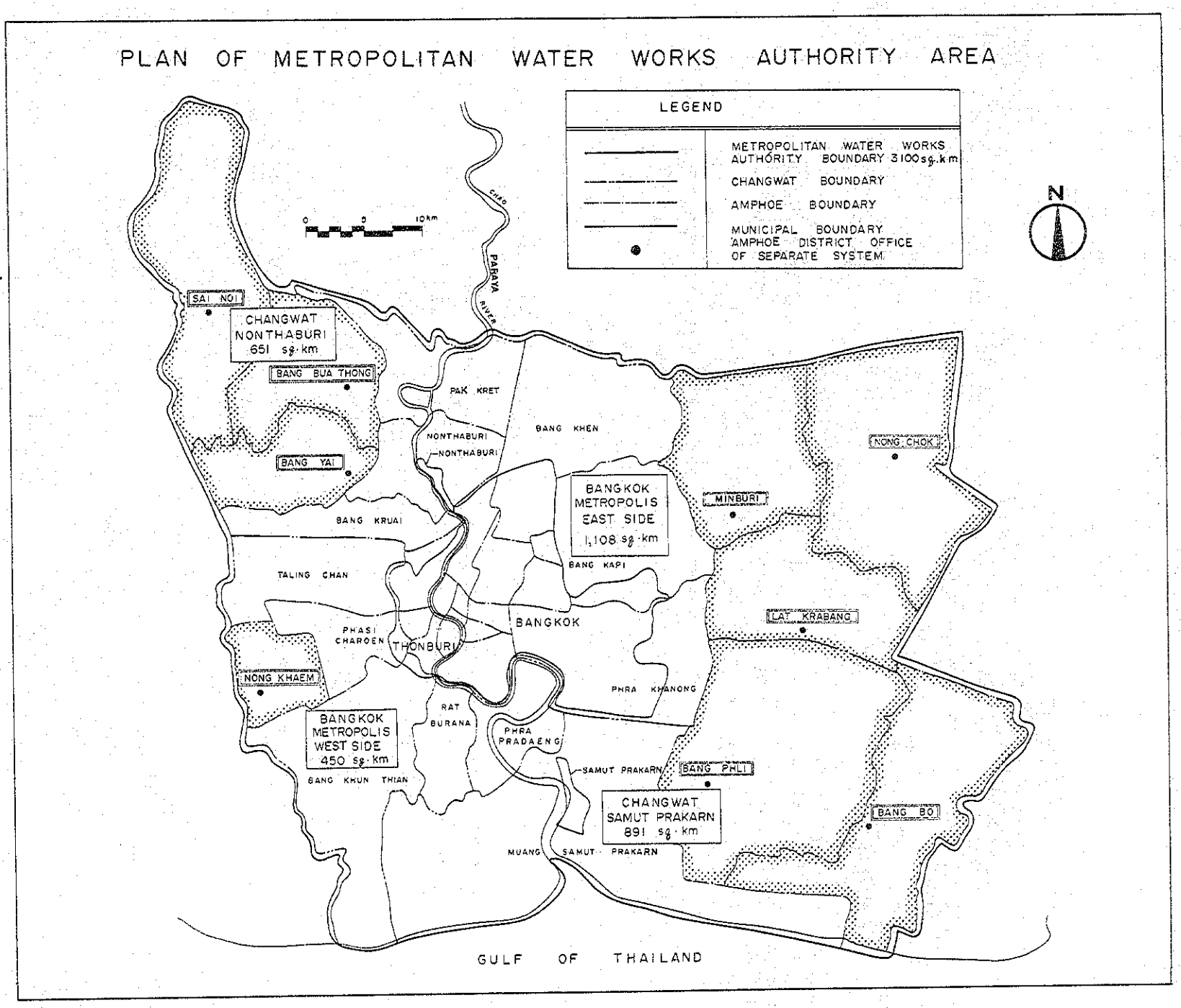
JULY. 2521 (1978)

JAPAN INTERNATIONAL COOPERATION AGENCY

SUMMARY OF FINAL REPORT
ON
SEPARATE SYSTEM OF
METROPOLITAN WATER SUPPLY

Contents

PLAN OF METROPOLITAN WATER WORKS AUTHORITY AREA



CHAPTER I

INTRODUCTION

1-1 Foreword :

The drawing up the master plan of the water supply and distribution system in Metropolitan Bangkok was committed to the U.S.consulting firm - Camp, Dresser & Mckee (C.D.M.)- by the Metropolitan Water Works Authority (M.W.W.A.) in Dec. 1968, and C.D.M. finished its master plan in Feb. 1970.

The fundamental concept reflected in this master plan consisted of dividing the total M.W.W.A. area into two service areas: the Central System and the Separate System. In the Separate System, 9 Amphoes (Sai Noi, Bang Bua Thong, Bang Yai, Nong Khaem, Nong Chok, Min Buri, Lat Krabang, Bang Phli and Bang Bo), all located at fringe areas in Metropolitan Bangkok, were chosen as the study areas for water supply planning. This water supply and distribution system for the Separate System consisted of individual services from the original water sources (groundwater) in each Amphoe, and this plan was isolated from the Central System for the supply of water to the central areas of Bangkok.

After that, the Feasibility Study for Separate System was undertaken by the Japanese Government between in Mar. 1972 and in Mar. 1973; but that study included only 5 out of the 9 Amphoes.

This feasiblity study was mainly undertaken for the purpose of drawing up a total water supply system for all 9 Amphoes, including the review of 5 Amphoes under the previous survey, and was executed by Japan International Cooperation Agency (J.I.C.A.) between in Jan. 1977 and in July 1978. But additionally, at the commencement of this study, J.I.C.A. was requested by M.W.W.A. to include the Housing and Industrial Projects which were planned to be progressively developed in the vicinity of 9 Amphoes.

This requirement was accepted and the planning study was carried out accordingly to also include 7 development areas and an airport area located outside the confines of the Central System area. The general locations of the included Amphoes and development areas are indicated on Fig. 1-1.

The 9 Amphoes which comprise the Separate System are areas outside of central Bangkok and mainly populated villages which center around the larger Klong. Other than Sai Noi, these Amphoes have at present some more or less standard water supply systems but these facilities are small in scale and not adequate to maintain a sufficient supply of water of good quality. It is the sincere hope of the Amphoe residents that they can be supplied with a wealth of good water in the foreseeable future. And, behind the efforts of this study and planning is the since wish that those people will realize that dream all the sooner.

But, desire alone is not the only compelling reason for improved water supply services. As time goes on, Bangkok and the Amphoes will expand, population will increase, new residential, commercial and industrial areas will come into being, and so on; and this will happen throughout a very wide area around Bangkok. Thus, as time goes on, demands for water will be greater and greater, and thus the ever more urgent need for the comprehensive Water Supply System.

The contents of this feasibility study is summarised as follows :

1) Estimation of water demand in the planned study areas.
2) Survey of water sources to be available, including Central System.
3) Study of alternative plans for water supply system.
4) Selection of the optimum and feasible water supply plan.
5) Estimation of the construction cost and financial schedule for the optimum and feasible water supply plan.

Fig. 1 - 1
WATER SERVED AREAS

N

SAI NOI
1,500 CMD

BANG BUA THONG
5,200 CMD

4,400 CMD BANG YAI

4,500 CMD
NONG CHOK

BANG CHAN
5,100 CMD
Ho.

MIN BURI
7,300 CMD

CENTRAL SYSTEM

LAT KRABANG
38,000 CMD
Ho.
In.
9,850 CMD

NAKHON CHAI SI RIVER

NONG KHAEM
40,000 CMD

LAT KRABANG
9,100 CMD

NEW AIRPORT
3,500 CMD

CHAO PHRAYA RIVER

Ho.
BANG KHUN THIAN
5,300 CMD

LEGEND	
SERVED AREA	
CENTRAL SYSTEM AREA	
In. : INDUSTRIAL AREA	
Ho. : HOUSING AREA	Ho.
NEW AIRPORT	

BANG PHLI
2,800 CMD

Ho. In.
BANG PHLI
- BANG BO
23,800 CMD

BANG BO
3,000 CMD

BANG POO
65,500 CMD
Ho. In.

KLONG DAN
20,700 CMD
In.

1-2 Significance of Feasibility Study and Outlook :

The social environment which has influence on a water supply greatly changes from year to year. The growth and expansion of cities today depends on the trend in industry and the concentration or dispersion of population and does not run a fixed course. Any water supply project should therefore be planned with a sufficient degree of flexibility to adapt it to the changes in its proposed service area so as to ensure the balance in water demand and supply.

The water supply project should be planned as a comprehensive project which blend with the regional characteristics of the area it covers. If the water supply project is planned from only an administrative point of view such as village, town, city and/or country, the effective utilization of the water resource, the proper distribution of water among various demands and the flexible operation of the water supply facilities will not be satisfied enough. Furthermore, a useless double or triple investment will be unfortunately made.

This report on the feasibility study of the "Separate System of Metropolitan Water Supply Project in Bangkok" contains, as its name implies, the results of a feasibility study of a separate water supply system planned to cover the 9 Amphoes surrounding Bangkok city and the related housing and industrial project areas. The important points of this feasibility study were the water source and the relationship between the separate system and the central system.

These two important points are also closely related to each other, however, especially the latter is considered to be most important because the central system is already under construction and its completion set for 2000. C.D.M. stated in its report submitted to M.W.W.A. in February 1970 that the separate system should be planned independently of the central system. However, when the changes in their environmental conditions are taken into account, it seems open to question whether C.D.M. view is still valid. That is, a question now arises as to whether the separate system project can be planned only from the standpoint of a water supply for the 9 Amphoes and related housing and industrial project areas.

However, it is also a fact that the comprehensive water supply project is rational on the one hand, while on the other it is irrational in that it needs a long construction period and involves a heavy investment. The public water supply is a nonprofit undertaking and is not allowed to raise the water charge to the consumer as easily as it desires. To avoid the heavy burdens of interest and depreciation expenses, the water supply authority naturally tries to cut the first cost of the water supply project as far as it can, eventually reducing the scale of the project depending on the case.

The separate system is a typical example. A part of the proposed service area of the separate system is now under the jurisdiction of the Provincial Water Supply Division, Public Works Department, Ministry of Interior and in this part water has never been charged for at a rate of more than 2 Bahts/m^3. In part, because of this historical background, the water supply authority seems to have little mind to promote a long-term, comprehensive water supply project which would put a heavy strain on its financial resources.

J.I.C.A., squarely facing the fact that the community poepole of the 9 Amphoe Towns have long suffered from a water supply shortage, has conceived an emergency program by which to allow them the privilege of using groundwater, and proposed its feasible plan to M.W.W.A. The plan is discussed in detail in Chapters 2 and 7, of Final Report.

However, as a further field survey is necessary to develop the feasible plan into a detail design, J.I.C.A. made relevant recommendations to M.W.W.A., as summarized below.

The water supply project has hitherto been planned by using an indirect approach consisting of electrical prospecting method and consultation of the data of the past years instead of employing a direct method, boring. For instance, the coefficient of aquifer could not be estimated otherwise than by consulting the data obtained in metropolitan Bangkok and the specific capacity of the existing wells.

The proposed service area of the separate system is, of course, an important area of recharge to metropolitan Bangkok. Now that it can hardly be expected that water is directly returned to the aquifer

from the ground surface, to have control of the aquifers is by far more important than before from the standpoint of groundwater utilization. Aquifer control makes it an aim to determine the influence of groundwater utilization on the aquifer, to estimate the resulting change in the groundwater level, to prevent the undesirable consequence resulting from abnormal decline of the groundwater level and to prevent an unnecessary investment by planning the capacity of production wells according to the capacity of aquifers tapped.

In planning the separate system, it is necessary to review and forecast the changes of the groundwater level resulting from ground water use through 2000, based on the coefficient of aquifer to be tapped which would be estimated by the direct boring before the detail design. To this end, it should be recommended to take the following actions:

(1) A set of test wells should be bored to the planned depth in each Amphoe, including:

1) Test wells

A set of lifting and observation wells should be bored at 8 locations.

2) Electric logging and γ -logging should be carried out.

3) Yield tests should be performed to determine the coefficients of transmissibility, permeability and storage of aquifers to be tapped and the specific capacity of wells.

4) Analysis of water quality and grain size of aquifer sand.

(2) Information on the causal relation between the annual increase in groundwater pumpage on the one hand and the draw-down of the groundwater level, the salification of groundwater and land subsidence on the other should be obtained.

(3) The draw-down of the groundwater level due to groundwater use by the separate system will be mathematically simulated. That is, the groundwater balance in each Amphoe will be computated by using a mathematical model of the aquifer.

The proposed long-term, comprehensive water supply plan represents the most feasible of all the alternative cases in which the separate system is assumed to form a part of the central system. Since this plan presupposes the tapping the sources of surface water, including the Chao Phraya river, it is of absolute necessity to obtain prior consensus of the authority having rights to the sources of surface water to implement the long-term comprehensive water supply project. The development of water sources is not a matter which the water supply authority alone can decide upon since such a project is of national concern. The government of Thailand is therefore urged to undertake such a national project so as to pave the way for the promotion of regional water supply projects, as will be discussed in detail in Chapters 2 and 7, of Final Report.

Since it is within the power of M.W.W.A. to decide to divert water from the central system, it should consider the redistribution of water in planning the long-term comprehensive water supply system.

1-3 Outlook of Separate System:

The planning of the water supply in metropolitan Bangkok, including the reviewing of the separate system, is still in its very initial stage. A sufficient water supply is the prerequisite to the development of satellite cities around Bangkok city. To ensure a sufficient water supply, the question of water sources must be resolved.

As much water as needed can be obtained, if surface water is taken from a big river far away; but M.W.W.A., which alreacy faces a heavy financial burden by the construction of the central system project will be further pressed financially if an enormous investment is also to be made in the separate system. A practical approach to the implementation of the long-range separate system project would be to find temporary water sources which will get the project moving. To find such water sources it is necessary to study the possibility of utilization of groundwater and water from the existing Klongs. The possibilities of water sources will be explored by the surveys designed on the basis of this feasibility study. From groundwater surveys, predictions can be made as to yields of aquifers over a wide area and the extent of salinification of groundwater. The surveys of the Klongs will reveal the contamination of water and from these predictions can be made as to the long-time suitability of the Klongs as a water source.

1-4 Proposed Plan of Separate System :

(1) Specifications :

1) Planned Service Areas :

i) Amphoes :

Right Bank : 4 Amphoes
Left Bank : 5 Amphoes } 9 Amphoes

ii) Adjacent Development Areas :

Right Bank : 1 Development Program
Left Bank : 7 Development Programs

2) Target Year : 2000 AD (Start to Supplying at 1982)

3) Size of Areas :

Administrative Area (9 Amphoes) : 1,553 Km^2
Served Area (9 Amphoes) : 168 Km^2

4) Population (At 2000 AD) :

	9 Amphoes	Development Program	Total(person)
Administrative Area :	694,629	295,496	990,125
Served Area :	363,900	442,006	805,906
Population Served :	273,725	442,006	715,731

5) Water Demand (Maximum Daily Water Demand)

9 Amphoes : 77,800 CMD
8 Development Programs 171,750 CMD } Total 249,550 CMD

6) Water Sources (At 2000 AD) :

Well : 42,900 CMD
Central System : 206,650 CMD } Total 249,550 CMD

(2) Future Water Requirements :

Separate System Estimate

	Year				
	1980	1985	1990	1995	2000
Population Served	188,471	379,840	555,676	662,552	715,731
Water Demand (CMD)	67,470	120,040	182,450	219,750	249,550

CHAPTER 2

DISCUSSION AND RECOMMENDATIONS

2-1 Consideration of Adjacent Development Area :

If the survey which was taken of 5 out of the 9 Amphoes to be covered by the separate system in 1972 is called as a first feasibility study, the survey which was taken by J.I.C.A. in 1977 can be called as a second feasibility study.

The second feasibility study began with a field survey which was continued for a period of two months from January 23 to March 26, 1977. On the first day of the visit of the Japanese survey team to Bangkok it was requested by the authority of Thailand to include the following investigations in the scope of its activities.

1) Adjacent industrial and/or residential area relating to the 9 Amphoes :

2) Review of the central system :

After being discussed it was agreed between M.W.W.A. of Thailand and J.I.C.A. of Japan that the J.I.C.A. would include 1) in its survey where possible; and undertake 2) only "in case it would be better for the separate system to divert water from the central system".

The adjacent industrial and/or residential area which is to be included in the scope of this feasibility study is divisible into 8 districts where 5 housing projects, 5 industrial development projects; and a new airport project are considered.

The entire water supply project of separate system becomes quite complex, when the adjacent industrial and/or residential area are included. Water demand of the entire water supply system in 2000 is estimated at 171,750 CMD, more than two fold the demand in the existing Amphoes (77,800 CMD in 2000 AD).

However, these adjacent development area projects play a significant role in the decentralization of the metropolitan population and sub-urban development; and viewing of their significance on a national level, the 8 adjacent development areas has been determined including in this feasibility study.

2-2 Water Sources :

(1) Groundwater :

The most important question in the feasibility study of the separate system is where to find an economically feasible water source. However, the fact must be faced that a water source which is rich, safe and cheap is extremely difficult to find, especially so when the separate system is to be expanded to cover the entire development program area.

It was revealed by electric prospecting survey that there were 8 aquifers at differing depths in the area to be supplied by the separate system. The data of the EGAT indicates that the four aquifers below 300 m yield are poor quality water and are not adequately recharged, and that the upper two aquifers are contaminated. Accordingly, the project area has only two aquifers (at a depth of 150 to 200 m below ground surface) which can be safely tapped.

In the metropolitan Bangkok area, however, about 900,000 CMD of water is drawn from the upper five aquifers, and the rate of withdrawing fresh water far exceeds the rate of recharge and to the extent that saline water intrudes these water supply aquifers for a distance as great as 900 m or so each year.

The legal restrictions of the use of groundwater in Thailand are not a subject of this feasibility study. Legal protection against unrestrained use of groundwater cannot be expected for the present. In any case, M.W.W.A. - which already withdraws nearly 320,000 CMD of water - should not overpump groundwater more than recharge amount.

The study for the recharged amount of the separate system was carried out by the procedure as shown in Fig. 4-1.
As a result of multiple studies, it appears that the vertical recharge cannot be relied on due to distribution of impermeable clay layers within the study area.

On the other hand, about 54,300 CMD of water can be expected from the holizontal recharge in the study area; thus, it can fill the demand of 37,800 CMD for the existing 8 Amphoes, excluding Nong Kheam; however, it cannot meet the total demand of 249,550 for the entire served area including the adjacent development areas.

Furthermore, when the undesired consequences of over-pumping in Bangkok and its vicinity are taken into account, the limit of groundwater pumpage should be determined after an extensive and detailed study.

The community people of the existing 8 Amphoes have long sufferred from a water supply shortage and should therefore be accorded the privilege of using groundwater by priority since there is a limit to the yield of this water source. The adjacent industrial and/or residential area should be supplied with water from other source, except for Bang Chan where a water supply project which plans to tap 5,100 CMD of groundwater is already under way. Accordingly, the total amount of groundwater which the entire separate system will be allowed to withdraw will be limited to 42,900 CMD.

(2) Surface Water :

When the use of groundwater is limited only to the existing 8 Amphoes, the adjacent development area cannot be supplied with groundwater. To supply this area is will be necessary to tap other sources like the Klong or a river. (The discussion of the central system will be deferred to Sec. 2-3).

As already pointed out in the feasibility study of 1973, the Klong water is markedly contaminated by organic matter so that the 5-day BOD of smaller Klongs such as the Klong Thawi Watthana and Phra Khanong is already as high as 5 ppm. The contamination of the Klong water has advanced to such extent that the smaller Klongs have been disqualified one after another for a source of water supply.

On the other hand, relatively larger Klongs like Sam Wa and Sip Sam still yield not only quantity but also quality for the drinking purposes. The detailed discussion of the Klongs as a water source will be deferred to a later chapter. Both the observed and assumed values of 5-day BOD of the water of Klong Sam Wa are below 1 ppm so that it well qualifies as a source of potable water. However, its tapping is another study, since the Royal Irrigation Department (RID) has the water rights to the Klongs. M.W.W.A. should

therefore, firstly sound out RID regarding the possibility of tapping the Klongs as a water source. Any plan to tap the Klongs which will not be approved by RID is nothing but a house of cards.

The use of river water, on the other hand, presupposes the development of a new water source. The development of such a new water source is not a problem of the separate system alone but a basic one which the Greater Bangkok Water Works, including the central system, now faces. M.W.W.A. which now depends on only the Chao Phraya river for a water supply source should take action as early as possible to study the possibility of tapping the other rivers including the Nakhon Chai Si river which has a suitable intake site about 80 km upstream from its estuary.

Many of the problems concerning the use of surface water are political as well as technical, as mentioned above. Since the separate system is required to commence service as soon as possible, M.W.W.A should begin negotiations with the competent authorities as early as possible in order to acquire the water rights to the Klong and should lay out a plan to tap rivers as a spare, if it decides to rely on surface water to fill the demand on the separate system.

An attempt to even overpump groundwater to fill the demand on the separate system instead of using a political and technical approach for tapping the Klongs or rivers should in no case be allowed. Should it be allowed, M.W.W.A. will have to take such serious consequences as the land subsidence of the Greater Bangkok area and the intrusion of sea water into the water supply aquifers in the area.

2-3 Relationship with Central System :

(1) History of the Feasibility study :

As mentioned in Sec. 2-1, the reviewing of the central system by J.I.C.A. as an additional assignment was accepted with the proviso "in case it would be better for the separate system to divert water from the central system".

The idea of diverting water from the central system apparently arose when a feasibility study of the water supply project for 5 Amphoes was conducted in 1972. As a matter of fact, part of the feasibility study report prepared in March 1972 reads as follows:

"When Dr. S. Naito carried out a basic survey for the separate system from September 1971 to March 1972, it was never mentioned in metropolitan Bangkok that the decided service area of the central system should be expanded to include the service area of the separate system or water should be diverted from the central system to fill the demand on the separate system."

Those days the separate system was not related to the central system, reflecting an easy-going view that, as C.D.M. stated in its report, the separate system would be relatively easy to build. There was a view that as much water as wanted could be obtained by digging wells. However, the groundwater survey which was taken in Nong Khaem following the basic survey led by Dr. S. Naito proved a failure and the groundwater in Sai Noi was found to be contaminated by saline water. Confronted with an unexpected situation, the persons charged with the water supply project had to review the separate system from the standpoint of water source.

In other words, it became necessary to find a relatively easy solution to the problem by turning to the central system for a water supply. Needless to say, the central system was planned as an independent system and was already under construction. It was therefore difficult to fill all the demand on the separate system with water diverted from the central system and it was economically disadvantageous to divert water from the central system to the separate system far away. As a result, the possibility of supplying Nong Khaem near Thon Buri with water diverted from the central system was studied.

(2) Water Source of the Central System :

Since the separate system accounts for only 5 % or so of the central system, it may not be realistic to discuss the water source of the central system even if the separate system is to rely on the central system for water.

However, there is only 25 m^3/sec or 2,160,000 CMD of water exists in the flow of Chao Phraya river for the purpose of water supply (See Note 1). As is clear from Table 4-B, this water source cannot fill the demand later than 1982; that is, the first stage.

On the other hand, the Nakhon Chai Si river, which could supply the service area of the separate system on the right bank of the Chao Phraya river, if developed, is a tributary of the Chao Phraya river. And, it is reported that RID has a plan to limit the amount of water withdrawn from the Chao Phraya river to 50 m^3/sec, and this to be allocated as 30 m^3/sec to prevent the intrusion of sea water into the resource and the remainding 20 m^3/sec to supply the community.

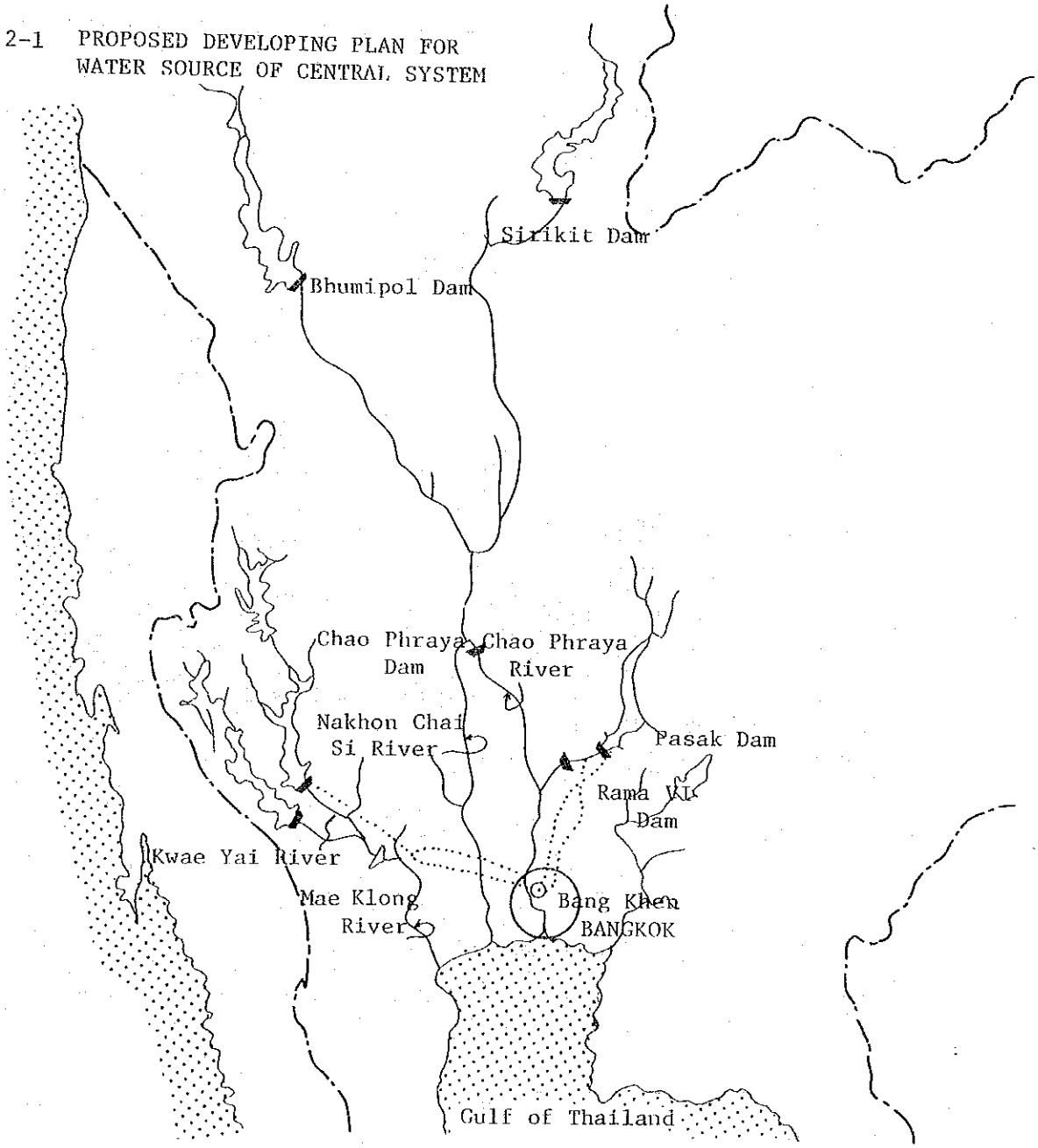
The demand for surface water in 2000 is expected to be such that it cannot be filled unless water is taken at a rate of 70 m^3/sec. Even if water can be taken from the Chao Phraya river at a rate of 25 m^3/sec and from the Nakhon Chai Si river at a rate of 20 m^3/sec, there will still be a supply shortage of 25 m^3/sec. There are plans to develop such water sources as the Kwae Yai river about 150 km west of Bangkok and the Pasak river which is a medium tributary of the Chao Phraya river in order to make good the supply shortage. The plan to develop the Kwae Yai river seems impractical as water must be carried over a long distance by an aqueduct or through use of the existing agricultural channel. The plan to tap the Pasak river, on the other hand, also needs a long distance, if water is to be carried directly from the dam, but this plan will be relatively easier to implement if the existing channel is utilized. (See Fig. 2-1).

However, these development plans are under the jurisdiction of other enterprises such as Electricity Generating Authority of Thailand, and the government such the Royal Irrigation Department; and reckoning with these as new water sources presupposes prior agreement with such

an enterprise or government agency.

* NOTE 1 : Contrary to the hope that the water flow rate of the Chao Phraya river near its mouth would increase to 120 m^3/sec when the Sirikit Dam was completed, a recent survey taken by R.I.D. indicates that its water flow rate near the mouth will be only 85 m^3/sec. When the flow rate of 60 m^3/sec required to prevent the intrusion of saline water into the river is considered, the central system cannot take more water from this river than at a rate of 25 m^3/sec.

Fig. 2-1 PROPOSED DEVELOPING PLAN FOR WATER SOURCE OF CENTRAL SYSTEM



CHAPTER 3

ESTIMATION OF WATER DEMAND

3-1 General :

The water demand in target year 2000 was estimated by dividing the served area into Amphoe and Adjacent Development Area.

The water demand in Amphoes was calculated by multiplying the population to be served by the daily water demand per capita, and the population to be served was estimated by the settlement of the served area, forecasting the future population density, and house connection ratio.

The water demand of the adjacent development areas was estimated taking the plan of each project into consideration.

3-2 Served Area :

The proposed served area in target year 2000 was established considering the present regional conditions, future development plans and the results of field survey. In planning, the served area was precisely set up along the main Klongs and roads according to the present Amphoe town as the district center, except that in Nong Khaem the whole of the administrative area was decided as the served area. (See Fig. 1-1.)

As a result, the proposed served area is 168 km^2 of the total administrative area of 1,553 km^2 within the 9 Amphoes.

3-3 Population Density in Served Area :

The population density in the served area was estimated on the basis of the population density of Nong Khaem 3,000 persons/km^2 in year 2000, and consequently the population density between 1,500

persons/km^2 and 2,500 persons/km^2 was utilized considering the scale of each Amphoe. Also the population density of Nong Khaem up to year 2000 was at first calculated about the total population by using the Logistic Curve coming from the past population data of Nong Kaem and the records of the similar cities in Japan, and estimated on its result. (See Table 3-A.)

3-4 House Connection Ratio :

The planned house connection ratio in target year 2000 was uniformly placed at the rate of 75% for each Amphoe. (See Table 3-A.)

3-5 Population to be Served :

The population to be served in each Amphoe was estimated using the following method :

(population to be served) = (Served area)x(Population density in served area)x(House connection ratio)

The population to be served in Nong Khaem was calculated by multiplying the population of the administrative area assumed from the past data by the house connection ratio. The total population to be served was estimated as 273,725 persons and 442,006 persons in the 9 Amphoes,and in the only adjacent development areas, respectively.

3-6 Average Daily Water Demand per Capita:

The average daily water demand per capita was estimated based upon the data of 17 cities in Thailand which was obtained from the previous F.S. Report of 1973. (See Table 3-A.)
The maximum daily water demand per capita was estimated as follows:

(Maximum daily water demand per capita)
= 1.5 x (Average daily water demand per capita)

3-7 Water Demand in 9 Amphoes:

The water demand in each Amphoe was calculated by multiplying the population to be served by the average daily water demand per capita. The maximum daily water demand per capita of 9 Amphoes in year 2000 was estimated as 77,800 CMD and as is shown in Table 3-A.

3-8 Water Demand in Adjacent Development Area :

The water demand in the Housing and Industrial development areas was decided based upon the plans by the National Housing Authority and the Industrial Estate Authority. On the other hand, the water demand in a new airport was estimated by considering the average daily water demand per capita of Haneda International Airports and number of passengers of Don Muang Airport. In this result, the estimations of the water demand in the adjacent development areas in year 2000 is 171,750 CMD in total. The total water demand is shown in Table 3-B. Futhermore, the water demand of the total area in the Separate System in year 2000 was estimated about 249,550 CMD as follows.

Table 3-A

Separate System Estimate	Development Program Areas			
	9 Amphoes	(Ho.)	(In.)	Total
1) Served Area, sq.km.	168	-	-	-
2) Population to be Served, Person	273,725	442,006	-	715,731
3) Maximum Daily Water Demand per capita	220 - 300	200	-	349
4) Maximum Daily Water Demand,CMD	77,800	88,400	83,350	249,550

Note : (Ho) Housing Development Program
(In) Industrial Development Program

Table 3-A POPULATION AND WATER DEMAND AT 2000 A.D.

	Item / Amphoe	Area (Km^2)	Population (Person)	Served Area (Km^2)	Population Density In Served Area (Person/Km^2)	Population In Served Area (Person)	House Connection Ratio (%)	Population to be Served (Person)	Daily Maximum Water Demand Per Head (ℓ/c.d.)	Daily Maximum Water Demand (CMD)
Right Bank	Sai Noi	217	30,770	6	1,500	9,000	75	6,750	220	1,500
	Bang Bua Thong	115	65,251	18	1,750	31,500	75	23,625	220	5,200
	Bang Yai	96	37,142	16	1,650	26,400	75	19,800	220	4,400
	Nong Khaem	48	144,000	48	2,983	144,000	75	108,800	300	*7,600 32,400
	Sub Total	476	277,163	88	-	210,900	75	158,975	-	51,100
Left Bank	Nong Chok	236	64,743	18	1,500	27,000	75	20,250	220	4,500
	Min Buri	174	89,686	22	2,000	44,000	75	33,000	220	7,300
	Lat Krabang	124	65,445	22	2,500	55,000	75	41,250	220	9,100
	Bang Phli	324	117,511	11	1,500	16,500	75	12,375	220	2,800
	Bang Bo	219	80,081	7	1,500	10,500	75	7,875	220	*1,250 1,750
	Sub Total	1,077	417,466	80	-	153,000	75	114,750	-	26,700
Total		1,553	694,629	168	-	363,900	75	273,725	-	77,800

* { Water Demand of Out of Nong Khaem Area
  { Water Demand of Klong Dan

Table 3-B WATER DEMAND OF SEPARATE SYSTEM

(CMD)

Location					1980	1985	1990	1995	2000
Right Bank	North 2 Districts	Amphoe	Sai Noi		500	700	900	1,200	1,500
			Bang Bua Thong		2,000	2,700	3,400	4,300	5,200
			Bang Yai		1,300	1,900	2,700	3,500	4,400
		Sub Total			3,800	5,300	7,000	9,000	11,100
	Nong Khaem Districts	Amphoe	Nong Khaem		8,000	14,000	20,000	28,000	40,000
		Development Program	Bang Khun Thian	Ro	5,300	5,300	5,300	5,300	5,300
		Sub Total			13,300	19,300	25,300	33,300	45,300
	Total	Amphoe			11,800	19,300	27,000	37,000	51,100
		Development Program			5,300	5,300	5,300	5,300	5,300
		Total			17,100	24,600	32,300	42,300	56,400
Left Bank	East 3 Districts	Amphoe	Nong Chok		1,400	2,000	2,800	3,600	4,500
			Min Buri		2,900	3,800	4,900	6,000	7,300
			Lat Krabang		3,300	4,500	5,900	7,400	9,100
		Sub Total			7,600	10,300	13,600	17,000	20,900
		Development Program	Bang Chan	In	4,000	4,000	4,000	4,000	4,000
				Ho	1,100	1,100	1,100	1,100	1,100
			Lat Krabang	In	5,200	5,200	9,850	9,850	9,850
			Lat Krabang	Ho	2,730	13,330	26,000	38,000	38,000
			New Airport		1,500	2,000	2,500	3,000	3,500
		Sub Total			14,530	25,630	43,450	55,950	56,450
	South 2 Districts	Amphoe	Bang Phli		1,100	1,400	1,800	2,300	2,800
			Bang Bo		1,400	1,700	2,100	2,500	3,000
		Sub Total			2,500	3,100	3,900	4,800	5,800
		Development Program	Bang Phli - Bang Bo	In	1,100	3,800	3,800	3,800	3,800
				Ho	4,000	12,000	20,000	20,000	20,000
			Bang Poo	In	10,400	10,400	20,700	31,200	41,500
				Ho	5,040	17,760	24,000	24,000	24,000
			Klong Dan	In	5,200	12,450	20,700	20,700	20,700
		Sub Total			25,740	56,410	89,200	99,700	110,000
	Total	Amphoe			10,100	13,400	17,500	21,800	26,700
		Development Program			40,270	82,040	132,650	155,650	166,450
		Total			50,370	95,440	150,150	177,450	193,150
Grand Total		Amphoe			21,900	32,700	44,500	58,800	77,800
		Development Program			45,570	87,340	137,950	160,950	171,750
		Total			67,470	120,040	182,450	219,750	249,550

CHAPTER 4

WATER SOURCES

4-1 Groundwater :

The most important point in the feasibility study of the Separate System is to find an economically feasible water source. However, the fact must be faced that a water source which is rich, safe and cheap is extremely difficult to find, especially so when the Separate System is to be expanded to cover the entire adjacent development areas and a water source is considered from the view point of Greater Bangkok Water Works.

It was revealed by electric prospecting survey that there are 8 aquifers at differing depths in the Separate System area. The data of the EGAT indicates that the four aquifers below 300 m have poor water quality and are not adequately recharged, and that the upper two aquifers are contaminated. Accordingly, the project area has only two aquifers (at a depth of 150 to 200 m below ground surface) which can be safely tapped.

On the basis of the structural features, and the resistivity of aquifers resulting from electric prospecting, the Bangkok and Phra Phradeang aquifers and the Nakhon Luang and Nonthaburi aquifers may be categorized into two groups; and in the two groups, the Nakhon Luang and Nonthaburi aquifer group should be chosen as the water source for the water supply project, as suggested by the past data and the information obtained by the latest survey. (See Table 4-A.)

Regarding to the safe yield of the Separate System area, it was considered that 6 % of annual rainfall as a vertical recharge would change to groundwater in compliance with PIANCHAROEN study.*

However, after the detail study up to final stage, it became doubtful that the 6% of vertical recharge mentioned above could be

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* Charoen Piancharoen and Charoen Chuamthaisong, 1976 Groundwater of Bangkok Metropolis, Thailand.

relied upon due to existance of an impermeable clay layer, thus a revised study was made in 2nd step. (See Fig. 4-1.) As a result of the revised study, amount of horizontal recharge in the planned two tapping aquifers (Nakhorn Luang aquifer, and Nonthaburi aquifer) seems to be balanced in comparison with a planned water demand supplied by deep wells.

Furthermore, when the undesired consequences by overpumping in Bangkok and its vicinity are taken into account, the limit of groundwater pumpage should be determined after an extensive and detailed survey.

For selection of a feasible groundwater source, the electric prospecting and the study of relevant data were carried out, and consequently, the lower 2 aquifers, Nakhon Luang and Nonthaburi aquifers, were selected as the feasible groundwater sources. The recharge amount of these 2 aquifers in the Separate System area was estimated by the procedure as shown in Fig. 4-1.

At present, the groundwater of 900,000 CMD is tapped from the upper 5 aquifers in the metropolitan Bangkok area. This amount far exceeds the recharge amount that the saline water intrudes toward upstream by 900 meters a year and the groundwater table is declining year by year.

Under these conditions, the groundwater stored in the selected 2 aquifers in the sorrounding area of Bangkok horizontally flows into the aquifers in the central Bangkok area. This horizontal recharge amount of groundwater is estimated as 86,000 CMD, and the amount of 54,300 CMD out of 86,000 CMD is considered to be available for the Separate System area.

As a result, the utilization of groundwater was limitted only in the 8 Amphoes (excluding Nong Khaem) and Ban Chan development area, and the total amount of groundwater utilized in these areas was estimated as 42,900 CMD.

In planning the groundwater supply plan in the metropolitan Bangkok, it is important to estimate the correct values of the coefficients of aquifer, transmissibility, permeability etc. by test wells. Thus, before the detail design of the groundwater supply plan, the survey of Future Step as shown in Fig. 4-1 shall be necessary to obtain abovementioned values.

U.S. Consultants firm of Metcalf & Eddy (M & E) groundwater monitoring report gives a valuable recommendation for the Separate System based upon past data, as for example, about well depth at each Amphoe, well structure and new groundwater quality results. This recommendation may be useful during the comprehensive study to be undertaken in the future step.

4-2 Surface Water :

The object of this study is to choose the feasible surface water sources for the Separate System in terms of water quantity and quality. The surveyed surface water sources are as indicated on Fig.4-2, and briefly commented on as follows :

(1) Klong Thawi Watthana (R-1):

Klong Thawi Watthana had ever been recommended as a water source for the Amphoe Nong Khaem in the feasiblity study of 1973. However, at this time BOD was measured to establish a reference for future conditions of pollution. From this it was found that it already exceeded 4 ppm which seems to be an allowable limit for water treatment. Also, quantity of water is very small in dry season. Therefore, this Klong is not adequate for a water source.

(2) Klong Mae Nam Om (R-2) :

Klong Mae Nam Om is well-known as one of the tributaries of Chao Phraya River. The water quantity is stable, and judging from the water quality analysis, its quality is acceptable as a water source. Therefore, this Klong is considered to be feasible for a water source for the right bank area of Chao Phraya River.

(3) Klong Phra Phimon (R-3):

This Klong flows through the vicinity of Sai Noi. The organic water pollution is already high, and water quantity is unstable. Therefore, this Klong cannot qualify as a suitable water source.

(4) Nakhon Chai Si River (R-4):

This river is the main tributary of Chao Phraya River and seems to be a feasible water source. As to the problem of water quality, the intrusion of salt water into the river was investigated. According to the past data and current sampling data, there appears to be adequate so long as water is taken from a point about 80 km upstream.

(5) Klong Phra Ong Chao Chaiya Nuchit (L-1):

This Klong is located to the east of Bang Bo, and the water quality is fairly clear. However, the amount of 15,000 CMD water is already being used for the existing Water Supply System. Furthermore, about 110,000 CMD of water will be required for the south 2 districts and south development areas. Therefore, water quantity is insufficient for a planned water source.

(6) Klong Phra Khanong (L-2):

This Klong runs through Amphoe Lat Krabang and there exists a heavy concentration of private houses on both banks in this Klong. From the fact that BOD tests show a value of more than 4 ppm, it is somewhat doubtful for a water source.

(7) Klong Sam Wa & Klong Sip Sam (L-3, L-4):

These two Klongs are situated at northern part of Min Buri and Nong Chok. The water quantity of 0.1 m^3/sec and 2.5 m^3/sec is to be available for water sources in Klong Sam Wa and Sip Sam, respectively. Water quality of both of these Klongs is good. Unless the BOD load exceeds the allowable value, due to contamination resulting from a much higher concentration of private homes along these Klongs, they can be considered as available as water sources.

As the results of this survey, it was seen that Klong Mae Nam On and Nakhon Chai Si River on the right bank area of Chao Phraya river and Klong Sam Wa & Klong Sip Sam on the left bank area are to be feasible for water sources. However, for utilization of these surface water sources, permission will be needed from the Royal Irrigation Dept. (RID), which is responsible for the administration of water right. In addition, the study and investigation of the pollution sources from the private houses, or other water pollution sources, are also necessary, because the water quality of Klongs are much effected by the way people use them.

The utilization of Nakhon Chai Si River is a most important problem to be solved, because M.W.W.A., which is now utilizing only the Chao Phraya River as a water source for water supply, is considering Nakhon Chai Si River as the second water source.

This is meant not only as the problem of Separate System but also the problem of Greater Bangkon Water Works including the Central System. Therefore, it is expected that this problem should be solved as soon as possible.

4-3 Central System:

(1) Review of the Central System :

Nobody would refuse that the water supply project in Nong Khaem will be a poor investment, if the water works there will not rely on the Central System for a Water Supply. It must be also a fact that other districts to be covered by the Separate System were considered in the same way as Nong Khaem. However, the scope of work agreed on between M.W.W.A. and J.I.C.A. set a certain limit on the review of the Central System and it is, in principle, not permitted to make any significant changes in the detail design of the Central System which was made by C.D.M. at the expense of a great deal of time and money.

The basic plan of the Central System generally consists of taking raw water from more than one water source, producing purified water in Bang Khen treatment plant (final planned capacity : 4,800,000 CMD) and the two existing treatment plants (Sam Sen treatment plant with a present capacity of 680,000 CMD, and Thon Buri treatment plant with a present capacity of 170,000 CMD.) In year 2000 the existing treatment plants, Sam Sen and Thon Buri, will directly supply water to the served area; and Bang Khen treatment plant will supply water to 13 service reservoirs through a system of underground transmission lines. By that time the total treatment capacity will be 5,422,000 CMD.

When the diversion of water from the Central System is considered, Bang Khen treatment plant acquires importance as a plant which will have a direct relationship with the Separate System. Accordingly, the review of the Central System is mainly concerned with Bang Khen treatment plant. However, the scope of work does not in principle permit the review of the facilities forward of the treatment plant such as water source, waterway between water source and treatment plant, and detailed treatment facilities.

Therefore, the review of the Central System in this study was limitted to the following :

1) Check of the treatment capacity of Bang Khen treatment plant.

2) Study of the transmission line from Bang Khen plant.

3) Study of the capacity of service reservoirs which receives water from Bang Khaem plant.

(2) Demand-Supply Balance of Water :

The total water demand on the Separate System in 2000, including that in the adjacent development areas, is estimated to be 249,550 CMD. This volume accounts for only 5.3% of the demand on the Central System of 4,698,000 CMD.
Thus, the planned capacity of the water treatment and transmission facilities of the Central System is large enough to meet the water demands of both the Separate and Central Systems, and Bang Khen treatment plant (final planned capacity:4,800,000 CMD) can fill not only the demand on the Central System but the demand on the Separate System; and its main facilities, such as clarifier, rapid sand filter and clear-water reservoir, need no modification. (See Table 4-B.)

As the velocity of water flow in the pipes in 2000 is estimated to be 2.0 m/sec., the planned transmission line will not pose any problem from a hydraulic point of view. However, the transmission pumps will need some specification changes in order to cope with an increase in the water flow rate and in the head loss.

The service reservoirs of the Central System on which the Separate System will depend for water are Tha Phra (Right Bank), Pak Bo and Samrong (Left Bank). Tha Phra service reservoir is now under construction and is expected to be put in service upon completion of the Phase 1 project of the first

stage (1979). On the other hand, judging from the construction schedule of the Central System, Pak Bo and Samrong reservoirs will probably be put in service after completion of the Second Stage construction (1985). (See Fig. 4-3.)

Therefore, respective to the right bank, it appears that the Separate System construction can satisfactorily correlate with the Central System construction; whereas, respective to the left bank, it is required that the Second Stage construction of the Central System, especially the construction of the transmission line from Klong Toey to Pak Bo and Samrong service reservoirs, is completed as early as possible.

If it is feasible to divert water from the Central System to fill the demand on the Separate System, the plan to rely on it will be far more advantageous, both economically and technically, than the plan to tap an independent surface water source for the Separate System. To confirm the feasibility of the former plan, it is necessary to closely review the plan of the entire Central System. However, as mentioned earlier, a detailed review of the Central System cannot be undertaken unless M.W.W.A. decides officially to depend on the Central System to fill the demand on the Separate System and formally undertakes a more comprehensive review of the entire Central System.

Table 4-A ADOPTED AQUIFERS FOR SEPARATE SYSTEM

	Aquifer	Right Bank			Left Bank				
		Sai Noi	Bang Bua Thong	Bang Yai	Nong Chok	Min Buri	Lat Krabang	Bang Phli	Bang Bo
Proposed Well Depth		200 m	250 m	200 m	200 m	200 m	200 m	250 m	200 m
Depth of Bittin	Bangkok	60 m	60 - 65m	65 m	50 m	40 - 45m	65 - 70m	80 - 85m	70 - 75m
	Phra Pradaeng	115	100 - 110	110	80	100	130	140	130 - 135
	Nakhon Luang	150	150	150	150	160	160	170	170
	Nonthaburi	180 - 190	200 - 220	190	190	200	190	210	200
	Samkok	?	?	?	?	?	?	265 *	?
Thick-ness	Bangkok	40 m	40 m	40 m	5 - 10m	5 - 10m	35 - 40m	35 - 40m	35 m
	Phra Pradaeng	25 - 30	30	35	5	20	30 - 40	40	30 - 35
	Nakhon Luang	15	15	20 - 25	25 - 30	20	15	10 - 15	10 - 15
	Nonthaburi	10 - 15	25	25 - 30	15	15	15	20 - 25	15
Specific Resist-ance	Bangkok	2.0 - 7.0 Ω-m			3.9 - 5.0 Ω-m	1.4 - 6.9 Ω-m	2.0 - 9.8 Ω-m	5.0 - 7.8 Ω-m	2.5 - 23.0 Ω-m
	Phra Pradaeng	3.8 - 14.0			4.2 - 13.2	4.6 - 12.9	4.0 - 9.8	3.4 - 40.0	12.0 - 15.0
	Nakhon Luang & Nonthaburi	12.4 - 38.0			8.4 - 13.2	4.6 - 12.9	9.2 - 22.0	7.2 - 40.0	12.0 - 23.0

NOTE : ▨ Shows aquifer adopted for Separate System

▩ Shows aquifer for Separate System as recommended by M & E groundwater monitoring report

* Data of Depth from MWWA Test Well at Bang Phli

Fig. 4-1 STUDY OF RECHARGE

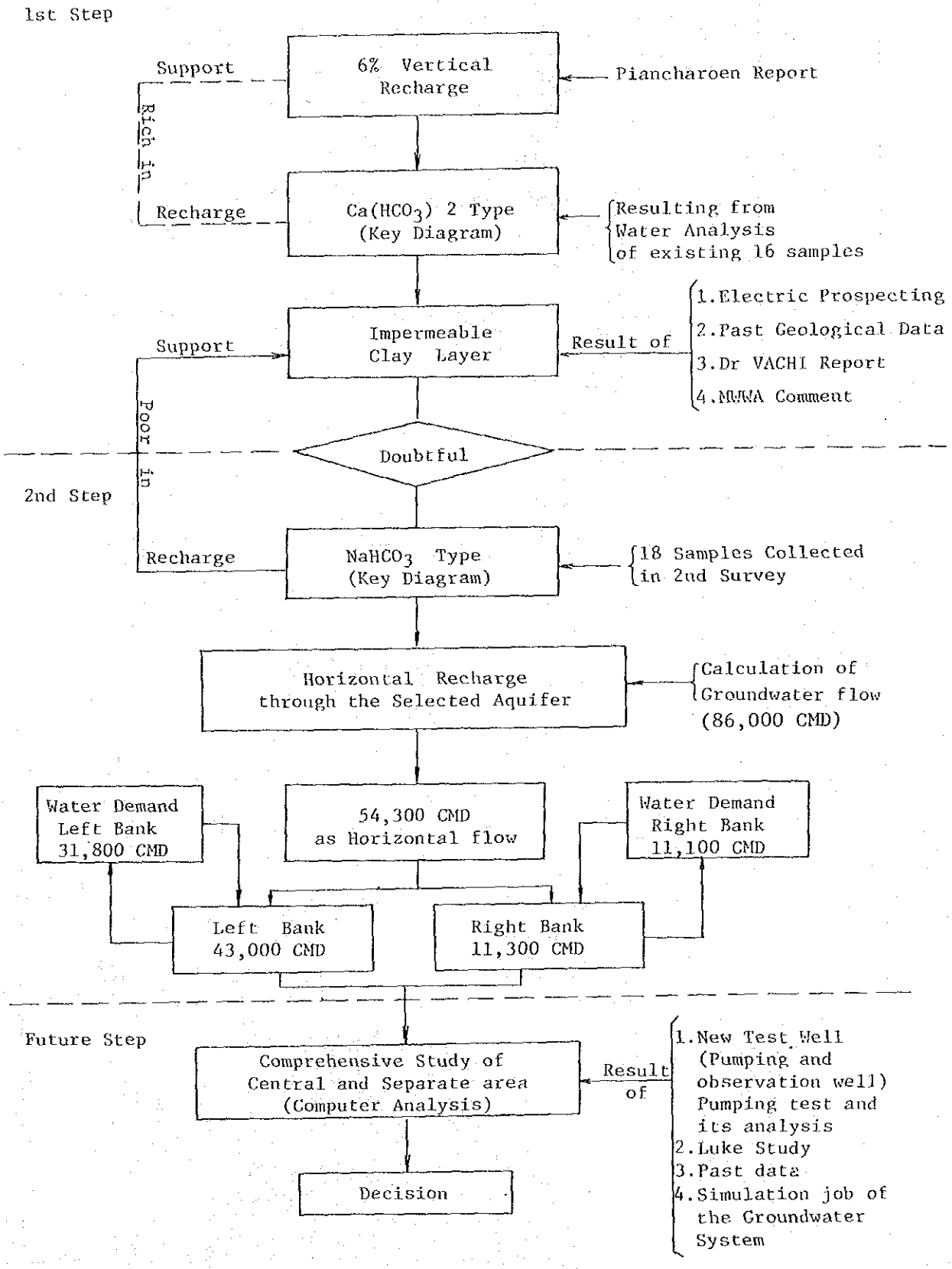


FIG 4 - 2
LOCATION OF WATER SOURCES

Table 4-B WATER DEMAND IN AREA SERVED BY BANG KHEN WATER TREATMENT PLANT

(CMD)

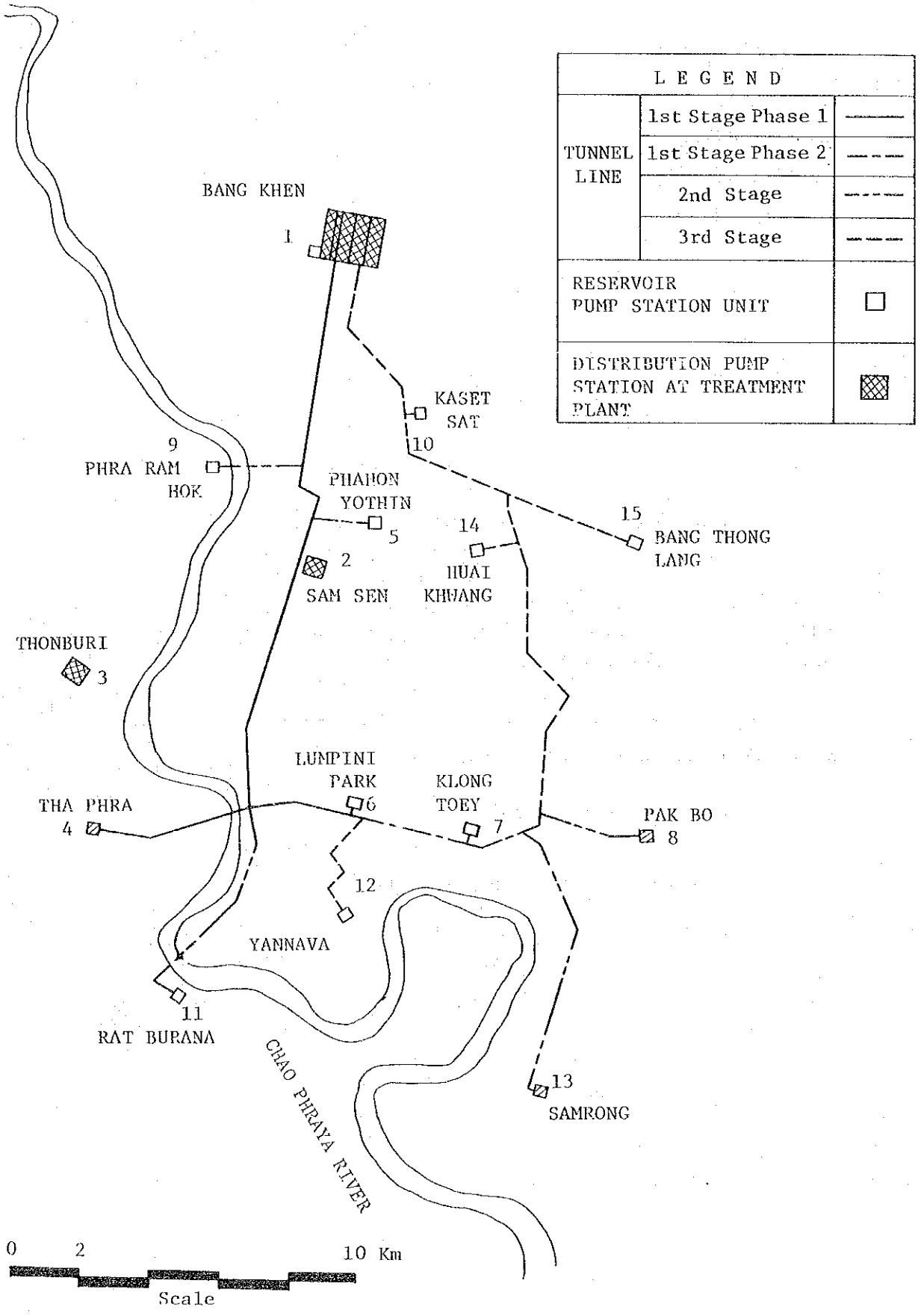
Item / Stage	Year (A.D.)	Central System		Water Demand Covered by Bang Khen W.T.P.			
		Capacity	Water Demand	Capacity	Water Demand (Central)	Water Demand (Separate)	Total
1st Stage Phase 1	1979	2,154,000	1,639,000	800,000	285,000	-	285,000
1st Stage Phase 2	1981	2,470,000	1,810,000	1,200,000	540,000	-	540,000
	1982	2,470,000	1,927,000	1,200,000	701,000	15,700	716,700
2nd Stage	1985	3,516,000	2,359,000	2,400,000	1,243,000	96,240	1,339,240
3rd Stage	1990	4,222,000	2,985,000	3,600,000	2,363,000	152,850	2,515,850
Final Stage	1995	5,422,000	3,749,000	4,800,000	3,127,000	183,850	3,310,850
	2000	5,422,000	4,698,000	4,800,000	4,076,000	206,650	4,282,650

DAILY MAX. WATER DEMAND BY WATER SOURCE

(CMD)

Area / Water Source		Well	Central System	Total
9 Amphoes	Right Bank	11,100	40,000	51,100
	Left Bank	26,700	-	26,700
	Sub Total	37,800	40,000	77,800
Development Program	Right Bank	-	5,300	5,300
	Left Bank	5,100	161,350	166,450
	Sub Total	5,100	166,650	171,750
Total		42,900	206,650	249,550

Fig. 4-3 TRANSMISSION LINE



CHAPTER 5

COMPREHENSIVE WATER SUPPLY PRJECT

The comprehensive water supply project of Bangkok will be planned to cover not only the 9 Amphoes to be supplied by the Separate System but the 8 adjacent industrial and/or residential areas around the 9 Amphoes.

The drawing up the water supply planning is roughly divisible into the right and left bank areas. The water source on the right bank is Wells, Klong Mae Nam Om, Nakhon Chai Si river and water diverted from the Central System; while water source on the left bank is Wells, Klong Sam Wa, Klong Sip Sam and water diverted from Central System. Accordingly, the served area is considered as the division into groups with respect to water demand uses and regional characteristics.

For the comprehensive water supply project, the 6 case of possible combination of water sources were selected on both the right bank and the left bank. The Basic construction cost for each case is summarized in Tables 5-A and 5-B.

Respective to the selection of water sources from the standpoint of construction cost, the following can be stated :

1) It would be economically advantageous to also depend on the wells for water, so long as the pumpage established according to the survey results is not exceeded.

2) The plan to divert water from the Central System will be more economically advantageous than the plan to use surface water, as the water supply by the former plan will need no treatment plant.

3) The water supply system will be quite expensive to build, if surface water is to be utilized over a wide area. The use of surface water should therefore be limited to an area of convenient size near the water intake point.

The major considerations which should be made in the use of each water source are noted as follows:

1) The use of wells should be allowed in only 8 Amphoes, excluding Nong Khaem, and in Bang Chan.

2) Phase 1 Project of the first stage of the Central System is now under construction and the detail design of the Phase 2 Project has already been completed. The plan to divert water from the Central System after Phase 2 Project must therefore be dealt with under subsequent construction schedules.

3) Agreement must be reached with the authorities having jurisdiction concerning the water rights when the plan to use surface water is to be carried out.

4) The comprehensive water supply project which plans to depend on surface water only and build several water treatment plants does not seem feasible from an economic point of view, for its construction cost would be about 2.2 times higher than that of the least expensive plan.

As a conclusion, the optimum feasible plans which would be the least expensive of the alternative cases are recommended in this study as follows :

1) Right Bank : Case - 4
2) Left Bank : Case - 5

Table 5-A COMBINATION OF ALTERNATIVES (RIGHT BANK)

District / Case	North 3 Districts	Nong Khaem District	Basic Construction Cost (฿)
Case - 1	W	N	735,302,000
Case - 2	N	N	873,660,000
Case - 3	K	K	882,309,000
Case - 4	W	C	406,936,000
Case - 5	K	C	489,372,000
Case - 6	C	C	481,017,000

Notes : W : Well
N : Nakhon Chai Si River
K : Klong Mae Nam Om
C : Central System

Table 5-B COMBINATION OF ALTERNATIVES (LEFT BANK)

District / Case	East 3 Districts & Bang Chan	South 2 Districts	East Developments	South Developments	Basic Construction Cost (฿)
Case - 1	W	W	K	K	1,761,384,000
Case - 2	K	K	K	K	1,908,000,000
Case - 3	W	W	K	C	956,415,000
Case - 4	K	C	K	C	1,059,751,000
Case - 5	W	W	C	C	847,725,000
Case - 6	C	C	C	C	920,800,000

Notes :
W : Well
K : Klong Sam Wa and/or Klong Sip Sam
C : Central System

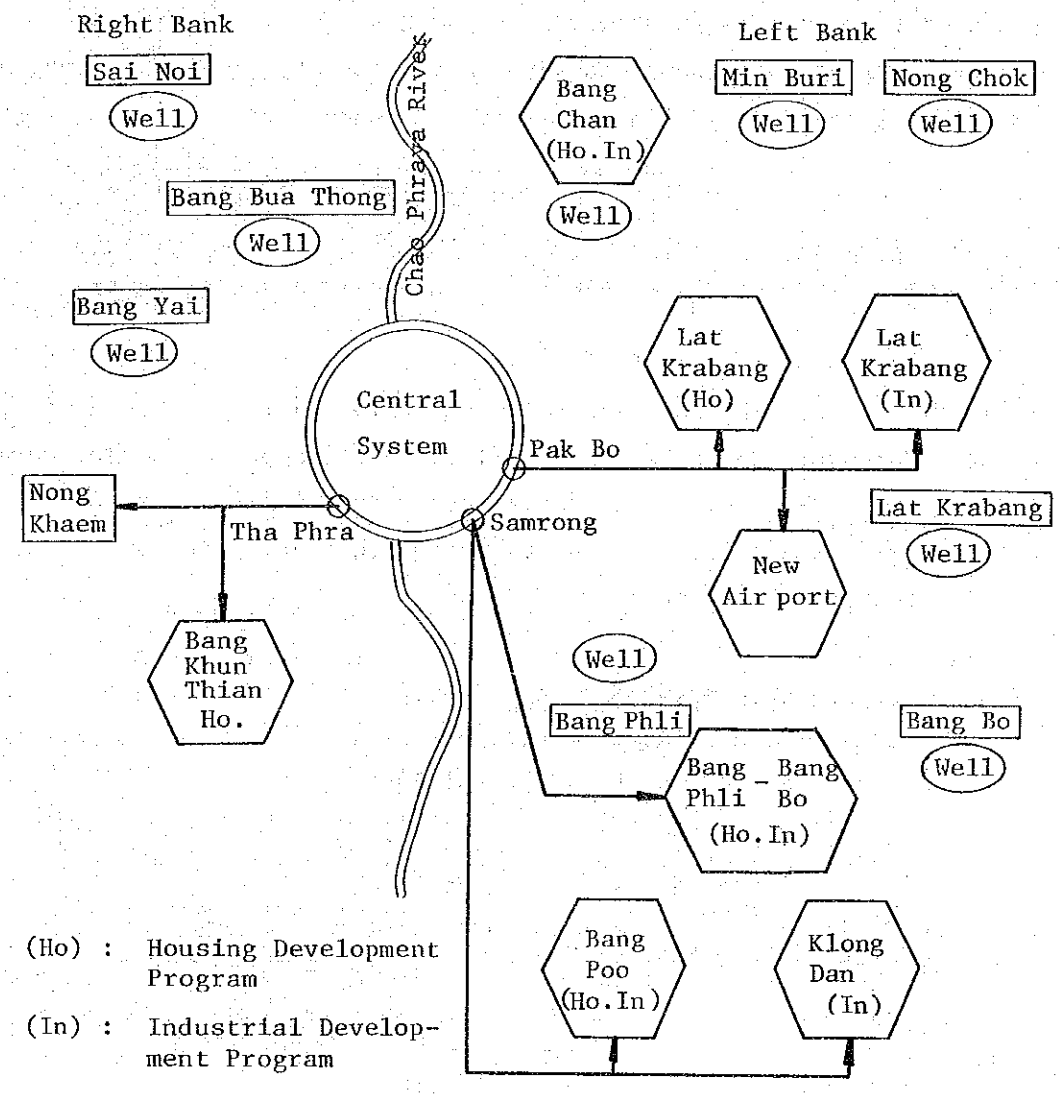
CHAPTER 6

OPTIMUM FEASIBLE WATER SUPPLY PLAN

6-1 Optimum Feasible Plan :

The following plan can be recommended as an optimum feasible water supply plan to supply the 8 Amphoes (excluding Nong Khaem) and Bang Chan with groundwater; and all other districts with water diverted from the Central System. This plan is graphically represented on Fig. 6-1 and 6-2 as follows :

Fig. 6-1 OPTIMUM FEASIBLE PLAN



The water demand in served areas using well water is of 42,900 CMD, and for this amount 33 deep wells (in sizes of between 200 mm and 300 mm in diameter, and in depths of from 200 m to 250 m) are to be installed. To avoid over-pumping the amount of safe yield ranges from 500 CMD to 1,520 CMD, and these wells are installed with an adequet separation distance to avoid adverse mutual influence.

On the other hand, the amount of water diverted from the Central System is 206,650 CMD, and accounts for 4.4 % in the planned water demand of 4,698,000 CMD on the Central System.

The groundwater is stored in the service reservoir after pumping and sterilizing by chlorination, after which it is pumped up to an elevated tank and distributed to the served areas by gravity flow. In the cases of inadequate pressure in the distribution mains booster pumps are installed.

The water diverted from the Central System is transmitted to the service reservoirs of the Separate System from the new pumping stations which are built adjacent to the existing stations of the Central System.

The range of planned facilities is from water source to distribution facilities in each Amphoe, and to transmission facilities in development areas. Moreover, the existing facilities still worth using (elevated tanks, deep wells, etc.) among water supply facilities are to be utilized essentially as is. In this plan, the facilities to be constructed are as follows:

1) Deep Well ..... 33 units (9 Development Areas)
2) Transmission Pipe from Deep Wells (ϕ300 - ϕ100) ... 37.4 km (9 Development Areas)
3) Transmission Pipe from Central System (ϕ900 - ϕ300) ...108.1 km (8 Development Areas)
4) Service Reservoir ... 9 units (9 Amphoes)
5) Elevated Tank ... 1 unit (Sai Noi)
6) Distribution Pipe(ϕ700 - ϕ100) ...374.8 km (9 Amphoes)

6-2 Order of Priority :

M.W.W.A. will have to invest an immense amount of money and a great deal of time in order to complete the Central System project which is presently being undertaken. The key to the successful implementation of the Separate System project in parallel with the construction of the Central System would be to minimize the first cost of the Separate System. In addition to financing, M.W.W.A. must also solve the problem of water sources; however, finding a suitable water source is not totally impossible.

In light of this way of looking at this question, the plan to supply groundwater to the 8 Amphoes should be discussed first. The Separate System is required to supply water not only the 8 Amphoes but also Nong Khaem and the adjacent development areas where housing and industrial development projects are planned. However, there is no source of groundwater to tap in Nong Khaem, and in the adjacent development areas a required amount of water cannot possibly be supplied in near future. Taking into consideration that the budget and water sources are limited,water should be supplied in an order of priority. If this principle is to be respected, the groundwater supply system to the 8 Amphoes should be immediatly as an emergency program.

As pointed out before, the plan to supply groundwater to the 8 Amphoes does require further survey before it can be undertaken. However, there is no doubt that this plan is the most feasible.

On the other hand, to implement a long-term comprehensive water supply project to cover not only the 8 Amphoes but also Nong Khaem and the adjacent development areas, the study of diverting water from the Central System should be carried out in parallel with the survey for the emergency program. As the diversion of water from the Central System can be decided by M.W.W.A. and at its own discretion without requiring consultation with other government agencies or authorities, it would take relatively little time to put its decision into action. As the survey and data analysis required to study the possibility of diverting water from the Central System should be carried out by consulting the existing data along with the progress of the

construction work of the Central System, it is recommended that the survey and analytical work be undertaken not on a consultant basis but on an expert basis, because experts would be usually able to stay in Thailand for a longer period of time.

If the diversion of water from the Central System is found not to be feasible, exploration should be started immediately in order to find a new surface water source. Since this exploration cannot be made without prior consent by other government agencies or authorities, necessary agreement should be obtained among the parties concerned. As it seems likely that the exploration for a new surface water source will chiefly consist of consulting the information and data which other government agency or authorities have accumulated, experts will lead the exploration.

The procedure for arriving at an optimum and feasible water supply plan is clearly shown in the flow chart of Separate System project implementation as shown in Fig. 6-3.

Judging from the necessity of emergency measure by the developing conditions of served areas, finance and technical realization of early implementation, the order of priority is roughly shown as follows:

1) Plan to supply ground water to the 8 Amphoes;
2) Plan to divert water from the Central System
3) Plan to tap a new surface water source

The Amphoes which take first, second and third order of priority are as follows: (See Table 6-A)

1st priority	Non Khaem
2nd priority	Lat Krabang
3rd priority	Min Buri

The establishment of an order of priority for the remaining 6 Amphoes is considered to be impossible at the present stage, but if necessary to do so, the order of priority for those should be determined considering the prospects of future development and other local conditions.

Fig. 6-2 SEPARATE WATER SUPPLY SYSTEMS

WATER DEMAND (CMD)

WATER SOURCE	RIGHT BANK	LEFT BANK	TOTAL
WELL	11,100	31,800	42,900
CENTRAL	45,300	161,350	206,650
TOTAL	56,400	193,150	249,550

N

RIGHT BANK (CASE-4)

WELL SAI NOI 1,500 CMD

WELL BANG BUA THONG 5,200 CMD

WELL 4,400 CMD BANG YAI

LEFT BANK (CASE-5)

4,500 CMD NONG CHOK WELL

MIN BURI WELL 7,300 CMD

BANG KHEN

KASET SAT

PHRA RAM HOK

PHAHON YOTHIN

SAM SEN

CENTRAL SYSTEM

HUAI KHWANG

BANG THONG LANG

BANG CHAN 5,100 CMD WELL

LAT KRABANG 38,000 CMD

9,850 CMD

THONBURI

THA PHRA

LUMPINI PARK

KLONG TOEY

NONG KHAEM 40,000 CMD

P Q = 45,400 CMD

P Q = 51,350 CMD

PAK BO

YANNAVA

WELL LAT KRABANG 9,100 CMD

NEW AIRPORT 3,500 CMD

RAT BURANA

CHAO PHRAYA RIVER

BANG KHUN THIAN 5,300 CMD

P Q = 110,000 CMD

SAMRONG

WELL BANG PHLI 2,800 CMD

BANG PHLI - BANG BO 23,800 CMD

BANG BO WELL 3,000 CMD

BANG POO 65,500 CMD

Q = 20,700 CMD.

KLONG DAN 20,700 CMD

NAKHON CHAI SI RIVER

LEGEND	
SERVED AREA	
CENTRAL SYSTEM AREA	
In.: INDUSTRIAL AREA	
Ho.: HOUSING AREA	
NEW AIRPORT	
PUMPING STATION	P
TRANSMISSION LINE	
SERVICE RESERVOIR	R
1ST STAGE TRUNK MAINS	
FUTURE TRUNK MAINS	
RESERVOIR PUMP STATION UNIT	
DISTRIBUTION PUMP STATION AT TREATMENT PLAN	

Fig. 6-3 FLOW CHART OF FUTURE STUDY IMPLEMENTATION

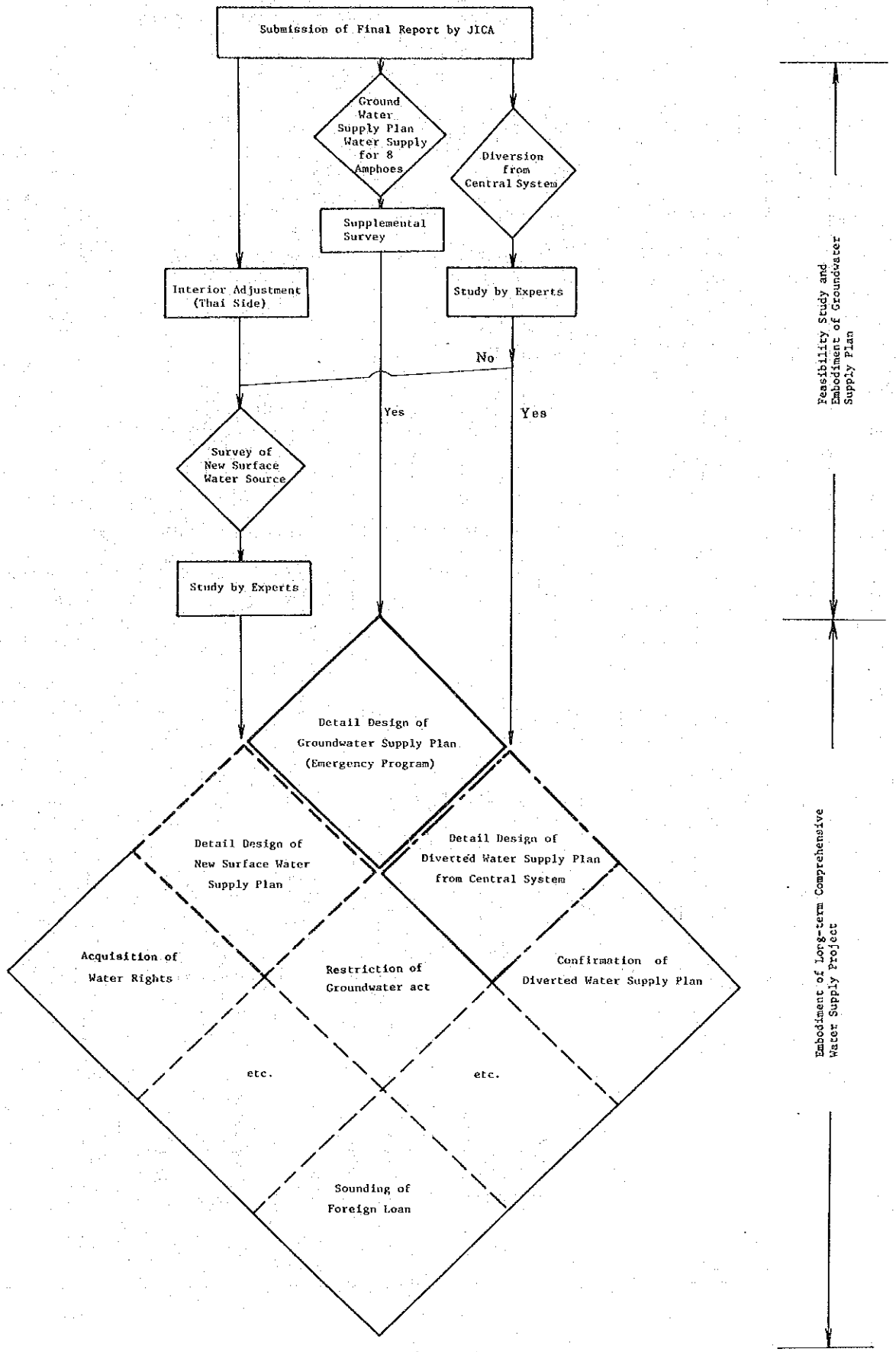


Table 6-A ORDER OF PRIORITY FOR 9 AMPHOES

Priority	Amphoe	Water Source		Starting Year for Implementation: Emergency Stage	Stage 1	Stage 2	Stage 3	Total	Reason of Priority
1	*Nong Khaem	Central System	Yc	1981	1987	1993	-		1) Groundwater in this district is poor from the standpoint of water quality. Although people have suffered from shortage of water due to lack of groundwater, it is not possible to make a water supply plan which relies on a water source of groundwater in this district in future. 2) As the Housing and Development project of Bang Khun Thian nearby this district is already starting, construction of a water supply system is needed as soon as possible. 3) As this district holds good promise of becoming one of the main satellites of Bangkok, the operating effects are great.
			Ca	22,900	11,200	11,200	-	45,300	
			C	298,884	34,383	15,818	-	349,085	
2	Lat Krabang	Well	Yc	1981	1984	1989	1994		
			Ca	4,560	1,520	1,510	1,510	9,100	
			C	52,340	13,736	10,008	7,199	83,283	
3	Min Buri	Well	Yc	1981	1986	1993	-		1) There is a large population to be served next to Nong Khaem, and this is located at the center on left bank area in separate system. 2) As rapid development of this district is expected, due to Lat Krabang Institute of Technology, the water system is needed to be in operation at an early stage.
			Ca	4,380	1,460	1,460	-	7,300	
			C	50,829	10,930	7,249	-	69,008	
4	Bang Phli	Well	Yc	1981	1984	-	-		1) In comparison with other six Amphoes, (except Nong Khaem and Lat Krabang) this district is relatively well urbanized at present time. 2) Housing and Industrial projects of Bang Chan adjacent to this district are just starting construction and urbanization is in very early stages. Therefore, while taking into account such an influence by developing progress, this is ordered as the 3rd priority.
			Ca	1,400	1,400	-	-	2,800	
			C	17,383	14,812	-	-	32,195	
5	Bang Bo	Well	Yc	1981	1984	1987	-		
			Ca	1,000	1,000	1,000	-	3,000	
			C	16,041	3,536	4,148	-	23,725	
6	Nong Chok	Well	Yc	1981	1983	1988	1994		1) In comparison with three Amphoes mentioned above, urbanization of these six Amphoes are still behind those Amphoes. 2) There does not appear to be any especially compelling factors respective to these areas which would dictate an order of priority. If a priority is to be set for these six Amphoes, it would most likely be based upon conditions of future development.
			Ca	1,890	870	870	870	4,500	
			C	27,200	9,201	4,599	5,061	46,061	
7	Bang Bua Thong	Well	Yc	1981	1985	1992	-		
			Ca	3,000	1,100	1,100	-	5,200	
			C	41,739	15,238	13,781	-	70,758	
8	Bang Yai	Well	Yc	1981	1985	1922	-		
			Ca	2,200	1,100	1,100	-	4,400	
			C	26,012	14,447	8,345	-	48,804	
9	Sai Noi	Well	Yc	1981	1989	-	-		
			Ca	500	1,000	-	-	1,500	
			C	16,872	6,589	-	-	23,461	
	Total		Ca	41,830	-	-	-	83,100	
			C	547,300	-	-	-	746,380	

NOTE : Yc : Construction Year (AD)
Ca : Planed Construction Capacity (CMD)
C : Construction Cost (1,000 ฿)

* Including Construction Cost for Bang Khun Thian Water Supply System.

CHAPTER 7

CONSTRUCTION COST AND FINANCIAL SCHEDULE

6-7 Construction Cost :

The approximate construction cost of the water supply was estimated depending on the water source and served area, assuming that the optimum feasible plan would be adopted. (See Table 7-A.) The construction cost was divided into the domestic and foreign currency portions. The domestic currency portion was estimated by referring to the material and labor costs derived from the data collected by M.W.W.A., while the foreign currency portion was estimated by referring to the Japanese market prices of main import items, such as pumps, machinery, electric apparatus, instruments and pipes (DCIP), plus ocean freight, import duties, and with a 20% allowance for miscellaneous expenses. In addition to the construction cost, administrative expenses, engineering fees and contingencies at the rates of 1.0 %, 3.0 % and 10.0 %, respectively, were added to arrive at the total construction cost indicated below. The above costs and prices do not include cost escalation. Cost escalation will be considered later herein under the discussion on financial schedule.

Construction Cost for Separate System (1)

(At 2000 AD)

Item	Construction Cost (£)
Basic Contract Cost	1,282,824,000
Administration (1.0%)	12,828,000
Engineering Fee (3.0 %)	38,484,000
Contingencies (10 %)	128,282,000
Total	1,462,418,000

Construction Cost for Separate System (2)

Water Source	Local Cost (฿)	Foreign Cost (฿)	Total Cost (฿)
Groundwater	320,308,000	93,645,000	413,953,000
Central System	528,675,000	519,790,000	1,048,465,000
Total	848,983,000	613,435,000	1,462,418,000

7-2 Financial Schedule :

The financial schedule is considered with respect to the optimum plan, and is planned by way of the trial of 56 cases based upon the combination of various factors as follows:

(1) Government Fund :

Government funds are of two sorts, namely 25% and 50%.

(2) Loan Conditions :

Loans are calculated using 4 conditions as follows :

Bank	Interest (%)	Term of Loan (Years)	Grace Period (Years)
OECF	3.25	25	7
Local	7.25	35	5
ADB	8.25	20	4
IBRD	8.85	20	4

(3) Water Charge :

This is calculated at rates of 2.5 ฿/m^3, 3.0 ฿/m^3, and 3.5 ฿/m^3 as the existing standard water charge is 2.0 ฿/m^3.

(4) Depreciation :

This value for each facility is as follows:

Item	Depreciation Ratio per Year
Submerged pumps for well:	0.100
Ductile cast iron pipes: (D.C.I.P.)	0.031
Asbestos cement pipes : (A.C.P.)	0.050
Structures:	0.020
Pumps :	0.050
Machinery :	0.040

(5) Cost Escalation Ratio :

6% compound rate per year.

(6) Effective Water Quantity :

0.75 effective ratio.

(7) Repair Expenditure :

0.3% of construction cost.

(8) Personal Expenditure :

28 persons up to 1985 AD.

35 persons after 1985 AD.

30,000 ฿ of personal expenditure per year.

(9) General Management Expenditure :

15 % of personal expenditure

(10) Power Cost and Chemical Cost :

This is calculated on the basis of existing charges to be used by M.W.W.A.

Results of calculations in accordance with above-mentioned conditions are as follows :

Assuming that the existing water charge (2.0 ฿/m^3) will be hopefully raised in furture, Case-39 is recommended and for reasons briefly as follows :

1) In cases where the water charge is 2.0 ฿/m^3 or 2.5 ฿/m^3, the balancing years of accumulated income and expenditure are all far beyond year 2030.

2) The water charge of 3.5 ฿/m^3 (although in half of the cases the balancing years are before year 2030) is not practical, judging from the existing charge of 2.0 ฿/m^3.

Recommended Financial Condition

Case No.	Water Charge (฿/m^3)	Government Fund (%)	Loan (%)	Balancing Year
Case-39	3.0	50	OECF 50.00	2026

Fig. 7-1 and Table 7-B show the balancing year for the recommended financial condition indicated above, and along with some of the other case conditions which were studied.

7-3 Benefit of this Water Supply System :

General speaking, the water supply has purposes as follows:

1) Water for life and daily living.
2) Water for public uses.
3) Water for social activities, commerce, and so on.

Therefore, it is a fundamental facility essential to individual and communal activities, and the water supply confers a great number and kinds of benefits upon the public. The benefits arising from the development of water supply projects can be classified into direct benefits and indirect benefits as shown in Fig. 7-2.

But, while these benefits in themselves are widely accepted and rarely questioned, there is always the matter of the capital investment : raising and expending the funds in order to build the facilities which ultimately provide the benefits.

One way to attempt evaluation of the real value of a public utility service is to translate and express the benefits in monetary

terms for comparison against the capital investment : determine a cost-benefit ratio. However, this is in fact extremely difficult to determine in practical terms as, for one thing, so many of the benefits are intangible and without monetary value.

Alternatively, it may be sufficiently realistic to accept the more general way of measuring the value of a public utility; that is, the effort and expense is of sufficient value if the operation is, or nearly so, on a self-paying basis.

Thus, if the operating expense can be paid for and the capital investment eventually returned by way of income realized from water charges, the populus can meanwhile and thereafter reap and enjoy the many benefits afforded by that investment.

Table 7-A BREAKDOWN OF CONSTRUCTION COST FOR SEPARATE SYSTEM

(UNIT : 1,000฿)

Water Source	District \ Year (A.D.)		1981	1983	1984	1985	1986	1987	1988	1989	1992	1993	1994	Total	Remarks
Ground Water	Sai Noi	C	16,872							6,589				23,461	
		Ce	20,095							12,508				32,603	
	Bang Bua Thong	C	41,739			15,238					13,781			70,758	
		Ce	49,712			22,912					31,158			103,782	
	Bang Yai	C	26,012			14,447					8,345			48,804	
		Ce	30,981			21,723					18,867			71,571	
	Nong Chok	C	27,200	9,201					4,599				5,061	46,061	
		Ce	32,396	12,313					8,236				12,857	65,802	
	Min Buri	C	50,829				10,930					7,249		69,008	
		Ce	60,538				17,421					17,372		95,331	
	Lat Krabang	C	52,340		13,736					10,008			7,199	83,283	
		Ce	62,338		19,485					18,998			18,288	119,109	
	Bang Phli	C	17,383		14,812									32,195	
		Ce	20,703		21,011									41,714	
	Bang Bo	C	16,041		3,536			4,148						23,725	
		Ce	19,105		5,016			7,008						31,129	
	Bang Chan	C	16,658											16,658	
		Ce	19,840											19,840	
	Sub Total	C	265,074	9,201	32,084	29,685	10,930	4,148	4,599	16,597	22,126	7,249	12,260	413,953	(20,697,650฿)
		Ce	315,708	12,313	45,512	44,635	17,421	7,008	8,236	31,506	50,025	17,372	31,145	580,881	(29,044,050฿)
Central System	Nong Khaem & Bang Khun Tian	C	298,884					34,383				15,818		349,085	
		Ce	355,977					58,089				37,909		451,975	
	East 3 Developments	C			248,367	1,108				1,108				250,583	
		Ce			352,313	1,666				2,103				356,082	
	South 3 Developments	C			446,935				1,862					448,797	
		Ce			633,986				3,335					637,321	
	Sub Total	C	498,977	-	695,302	1,108	-	34,383	1,862	1,108	-	15,818	-	1,048,465	(52,423,250฿)
		Ce	355,977	-	986,299	1,666	-	58,089	3,335	2,103	-	37,909	-	1,445,378	(72,268,900฿)
Grand Total		C	563,958	9,201	727,386	30,793	10,930	38,531	6,461	17,705	22,126	23,067	12,260	1,462,418	(73,120,900฿)
		Ce	671,685	12,313	1031,811	46,301	17,421	65,097	11,571	33,609	50,025	55,281	31,145	2,026,259	(101,312,950฿)

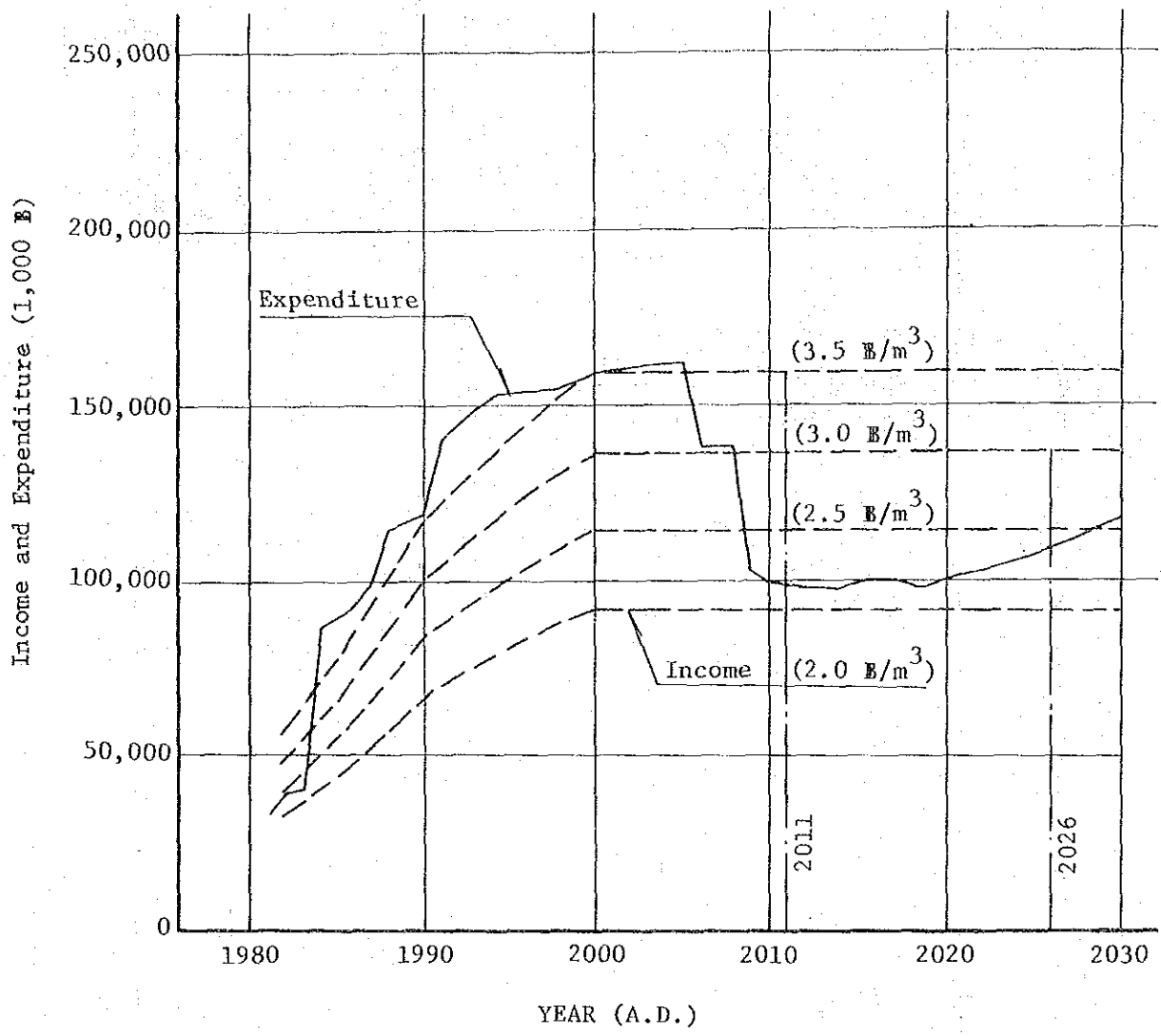
NOTE : C : Construction Cost (Incl. Administration, Engineering Fee and Contingencies)

Ce : Construction Cost (Incl. Cost Escalation at 6% Compound Rate Per Year)

Table 7-B ACCUMULATED BALANCE BY LOAN CONDITIONS

Case No.	Water Charge (₤/m³)	Covernment Fund (%)	Loan (%)				Balancing Year (A.D.)	Accumulated Balance (1,000 ₤)	Remarks
			Local	OECF	ADB	IBRD			
21	2.0	50	12.5	37.5	-	-	Beyond 2030	-2,198,512	(at 2030)
22	2.5	"	"	"	-	-	"	-1,203,584	(")
23	3.0	"	"	"	-	-	"	-208,656	(")
24	3.5	"	"	"	-	-	2015	786,272	(at 2015)
37	2.0	50	-	50.0	-	-	Beyond 2030	-1,875,067	(at 2030)
38	2.5	"	-	"	-	-	"	-880.139	(")
39	3.0	"	-	"	-	-	2026	25,141	(at 2026)
40	3.5	"	-	"	-	-	2011	58,650	(at 2011)
45	2.0	50	-	-	50.0	-	Beyond 2030	-2,485,526	(at 2030)
46	2.5	"	-	-	"	-	"	-1,490,598	(")
47	3.0	"	-	-	"	-	"	-495,670	(")
48	3.5	"	-	-	"	-	2021	499,258	(at 2021)
53	2.0	50	-	-	-	50.0	Beyond 2030	-2,581,164	(at 2030)
54	2.5	"	-	-	-	-	"	-1,586,236	(")
55	3.0	"	-	-	-	-	"	-591,308	(")
56	3.5	"	-	-	-	-	2022	403,620	(at 2022)

Fig. 7-1 BALANCE OF INCOME AND EXPENDITURE



Case No.	Water Charge (฿/m3)	Government Fund (%)	Loan (%)	Balancing Year (A.D.)
Case - 37	2.0	50	OECF - 50.0	Beyond 2030
Case - 38	2.5	50	OECF - 50.0	"
Case - 39	3.0	50	OECF - 50.0	2026
Case - 40	3.5	50	OECF - 50.0	2011

Fig. 7-2 FLOW CHART REGARDING WITH EFFECT OF THE BENEFIT