社会開発協力部報告書

KINGDOM OF THAILAND
MINISTRY OF INTERIOR
PUBLIC WORKS DEPARTMENT

FEASIBILITY STUDY
ON
THE SANITARY DISTRICT WATER WORKS PROJECT
IN
THE NORTH-EASTERN REGION OF THAILAND

MAIN REPORT

FEBRUARY 1986

JAPAN INTERNATIONAL COOPERATION AGENCY

KINGDOM OF THAILAND
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PREFACE

In response to the request of the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a feasibility study on the Sanitary District Water Works Project and entrusted the study to the Japan International Cooperation Agency. J.I.C.A. sent to Thailand a survey team headed by Mr. Satoshi Kadowaki from October, 1984 to September, 1985.

The team exchanged views with the officials concerned of the Government of the Kingdom of Thailand and conducted a field survey in the Northeastern Region of Thailand. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

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

February, 1986

KEISUKE ARITA
President
Japan International Cooperation Agency

Mr. Keisuke Arita
President
Japan International Cooperation Agency (JICA)
Tokyo, Japan

February, 1986

LETTER OF TRANSMITTAL

Dear Sir,

We are very pleased to submit herewith the Final Report on the Feasibility Study and Manuals for the Sanitary District Water Works Project in the North-Eastern Region of Thailand.

The field survey and study have been conducted in two stages October, 1984 through February, 1986. The Study Team has completed the feasibility study of the proposed ten sanitary district waterworks projects, and preparation of the design and the operation/maintenance manuals on the sanitary district waterworks as well as recommendations on improvement and rehabilitation of existing waterwork systems.

The Report consists of three volumes: Volume I - Main Report of the feasibility study, providing the results of study and analysis; Volume II - Appendices of the feasibility study, providing the detailed information on the technical and socio-economic aspects; Volume III - Manuals and Recommendations, covering the design manual, the operation and maintenance manual, and recommendations on the improvement of the existing facilities.

We do hope that realization of the proposed sanitary district waterwork projects can greatly contribute to the social and economic development in the subject sanitary district areas.

Finally, we take this opportunity to express our sincere gratitude to the Public Work Department of the Government of Thailand, Ministry of Foreign Affairs, Ministry of Health and

Welfare of the Government of Japan, and the Japan International Cooperation Agency (JICA), especially for Japanese Embassy in the Kingdom of Thailand and Advisory Committee which gave useful advices from time to time to the Study Team.

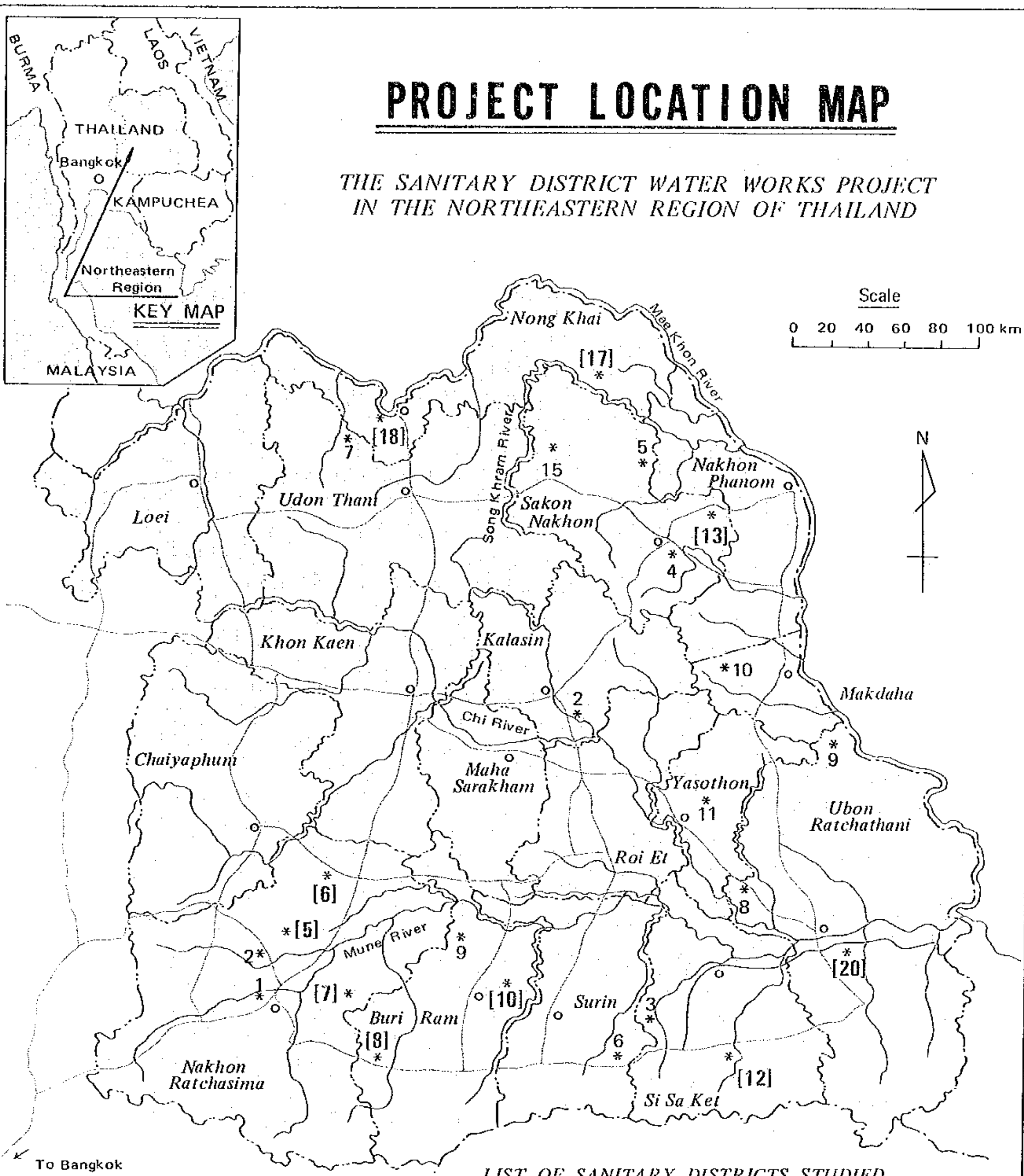
Respectfully yours,

S. Kadowaki

Satoshi Kadowaki
Team Leader for the Sanitary
District Water Works Project

PROJECT LOCATION MAP

THE SANITARY DISTRICT WATER WORKS PROJECT IN THE NORTHEASTERN REGION OF THAILAND



LIST OF SANITARY DISTRICTS STUDIED

New Sanitary District Without Water Works (NSD)		Existing Sanitary District With Water Works (ESD)	
2	Rong Kham	1	Cho Ho
[5]	Kham Sakae Sang	2	Non Thai
[6]	Nong Bua Lai	3	Prang Ku
[7]	Huai Thalaeng	4	Tha Rae
[8]	Nong Ki	5	Akat Ammuai
9	Hin Lek Fai	6	Sankha
[10]	Huai Rat	7	Ban Phu
11	Sai Mun	8	Khuang Nai
[12]	Khun Han	9	Chanuman
[13]	Kusuman	10	Khamcha-i
15	Don Khuang		
[17]	Phon Charoen		
[18]	Nong Song Hong		
[20]	Huai Kha Yung		

LEGEND

- National Boundary
- Provincial (Changwat) Boundary
- o Provincial Capital
- National Highway
- River
- * 2 NSD Studied
- * [5] Proposed 10 NSDs
- * 1 ESD Studied

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" D: PRELIMINARY DESIGN
" E: PROJECT IMPLEMENTATION AND PROJECT COST
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CURRENCY, CONVERSION FACTORS AND ABBREVIATIONS

Currency Equivalents (Average of the First Half of 1985):

US Dollar	US$ 1.00	= ฿ 27.0	= ¥ 250.0
Thai Baht	฿ 1.00	= US$0.037	= ¥ 9.259
Japanese Yen	¥ 1.00	= US$0.004	= ฿ 0.108

Units of Measurement :

Rai	= 0.16 hectares	= 1,600 sq.m
Hectare	= 6.25 rai	= 10,000 sq.m

Abbreviation and Glossary:

MOI	Ministry of Interior
PWD	Public Works Department, MOI
PWSD	Provincial Water Supply Division, PWD
PWA	Provincial Waterworks Authority
MWWA	Metropolitan Waterworks Authority
DOLA	Department of Local Administration, MOI
ARD	Office of Accelerated Rural Development, MOI
CDD	Community Development Department, MOI
MPH	Ministry of Public Health
DH	Department of Health, MPH
RWSD	Rural Water Supply Division, DH
MI	Ministry of Industry
DMR	Department of Mineral Resources, MI
GWD	Ground Water Division, DMR
MOAC	Ministry of Agriculture and Co-operatives
RID	Royal Irrigation Department, MOAC
SSIP	Small Scale Irrigation Programme
MSIP	Medium Scale Irrigation Programme
NESDB	Office of the National Economic and Social Development Board, Office of the Prime Minister
NSO	National Statistical Office, Office of the Prime Minister
WHO	World Health Organization, United Nations
JWWA	Japan Water Works Association
AWWA	American Water Works Association
JICA	The Japan International Cooperation Agency
changwat	Province
amphoe muang	Capital of Province
amphoe	District
SD	Sanitary District
ESD	Existing Sanitary District with Water Works

NSD	New Sanitary District without Water Works
tambon	Sub-district
muban	Village
Mae Nam	Large River
Nam	medium-size river
Lam	small river
Kwae	Tributary of a river
Huai	rivulet
mm	millimeter
cm	centimeter
m	meter
km	kilometer
ha	hectare
sq.km	square kilometer
l/s/sq.km	liter per second per square kilometer
cu.m/s	cubic meter per second
cu.m/hr	cubic meter per hour
MCM	million cubic meter
lcd	liter per capita per day
mg/l	milligram per liter
ms/sq.cm	millimeter semence per square centimeter
ppm	parts per million

CHAPTER I. INTRODUCTION

CHAPTER I. INTRODUCTION

1.1. Authorization and Report

The final report of the feasibility study on the Sanitary District Waterworks Project in the Northeast Region of Thailand was prepared in following aspects agreed upon in the Scope of Work concluded between the Government of the Kingdom of Thailand and the Government of Japan, on July 27, 1984.

The report covers the following four major subjects:

- The feasibility study on the waterworks for ten selected sanitary districts
- Design manual of the sanitary district waterworks project
- Operation and maintenance manual of the sanitary district waterworks systems
- Recommendation for improvement and rehabilitation of the existing sanitary district waterworks system

The final report consists of two parts; the first is two volumes which consist of a feasibility study report, composed of the main text and its appendix, and the other part is a series of manuals and recommendations for existing waterworks.

The feasibility report was prepared based on the field survey, review of the data and information available, elaborate study and analysis, a series of discussions between the Thai authorities concerned and the study team, and the interim reports as well as progress reports prepared in the course of the field survey.

1.2. Scope of the Study

The study is comprised of two phases; the first phase including information and data collection and preliminary field survey necessary for the selection of target Sanitary Districts and the second phase including feasibility study of the selected Sanitary Districts and all the other works necessary to achieve the objectives.

The following study was carried out on the 14 Sanitary Districts during the first phase.

- Data collection and analysis
- Study of socio-economic aspects
- Projection of population and water demand
- Review of present status of water supply
- Review of water sources using existing data
- Preliminary planning of water supply systems
- Preliminary design and cost estimate necessary for selecting Sanitary Districts for the feasibility study

Based on the studies made in the first phase, approximately 10 Sanitary Districts out of the 14 were to be selected for the detailed feasibility study.

The items to be studied in the second phase were as follows;

- Definition of the project area
- Projection of population to be served and water demand
- Study of water sources
- Study of required facilities and their layout
- Preparation of design criteria
- Study of available construction materials, labor force and local contractors
- Cost estimate for construction, operation and maintenance
- Study of water tariff system

- Study of organization, operation and maintenance plan
- Economic and financial analysis
- Preparation of implementation program
- Study of community participation
- Recommendation for improvement of existing facilities
- Preparation of design and operation maintenance manuals

1.3. Background of the Project

The Kingdom of Thailand covers an area of about 514,000 sq.km on the Indo-China Peninsula. The population in 1982 was estimated about 48 million and has been increasing at rate of 2.3% per annum.

Four natural regions are delineated by the pattern of rivers and mountains; North, Central Plain, Northeast and South.

There are a total of 712 sanitary districts in the country at present. 526 sanitary districts out of the total have the waterworks. The inhabitants in these sanitary district without waterworks, especially in Northeastern region, have been suffering from water scarcity.

Even in the sanitary districts with waterworks, inhabitants also suffer from insufficient water due to rapid growth of demand, inadequacy of raw water sources, old transmission and distribution pipelines, defective mechanical equipments etc.

Due to poorer and lower living standard, to the higher degree of scarcity of water when compared with other regions and to the necessity of promotion of security and political stability, the Subject Project will emphasize on the urgent construction of a public water supply system in the Northeastern region.

In response to the request of the Government of Thailand, the Government of Japan decided to implement a feasibility study on the Sanitary District Waterworks Project in the Northeastern region of Thailand.

1.4. Assignment and Counterpart Personnel

The following is the list of the members of the advisory committee, the members and their assignment of the study team and counterparts personnel contacted for the feasibility study on the project.

(1) Advisory Committee

Dr. Hidenori Aya (Chairman)	Professor Department of Civil Engineering, Musashi Institute of Technology
Mr. Tsutomu Sakagawa (Water Resources)	Chief of Technical Section, Water Works Division, Ministry of Health and Welfare
Mr. Shojiro Abe (Water Supply Facilities)	Chief of Planning Section, Waterworks Bureau, Kawasaki City

(2) Planning and Coordination

Mr. Mitsuo Kinjo (Coordination)	Senior Project Officer Social Development Cooperation Department, JICA

(3) Study team

(a) First Phase

Mr. Kazumasa Tomita	Team Leader
Mr. Akira Naotsuka	Water Supply System Engineer
Mr. Toshinobu Nakano	Hydrologist
Mr. Toshio Kamiya	Regional Planner

(b) Second Phase

Mr. Satoshi Kadowaki	Team Leader
Mr. Akira Naotsuka	Water Supply System Engineer
Mr. Toshinobu Nakano	Hydrologist and Water Source Planner
Mr. Ryoichi Kawasaki	Hydrogeologist
Mr. Hiroshi Hayata	Facility Design Engineer
Mr. Eiji Goto	Facility Design Engineer
Mr. Mitsutomo Anai	Project Economist

(4) Counterparts Personnel

Mr. Pojana Kantamala	Director General, Public Works Department (PWD)
Mr. Niyom Niyamanusorn	Chief Engineer, Public Works Department (PWD)
Mr. Prajaya Sutabutr	Chief of Technical and Planning Development Sub-division, PWSD
Mr. Pornchai Kositanurit	Chief of Water System Development Sub-division, PWSD
Mr. Banchong Thaicharoen	Chief of Administrative Sub-division, PWSD
Mr. Aroon Luangaroonlerd	Civil Engineer, PWSD
Mr. Thanade Dawasuwan	Civil Engineer, PWSD
Mr. Pisit Hongvanishkul	Civil Engineer, PWSD
Mr. Yongyuth Yunnalimpikul	Civil Engineer, PWSD
Miss Janya Pheantunyakorn	Civil Engineer, PWSD
Mr. Virat Udompong-lakana	Civil Engineer, PWSD
Mr. Tavee Kulpiyawat	Civil Engineer, PWSD
Mr. Chaiporn Siripornpibul	Geologist
Mr. Chaiyong Khnongkhaudom	Geologist
Mr. Vichai Chatsuwan	Project Economist

1.5. List of Subject Projects

The following are the new Sanitary Districts without water works (NSD) and the Existing Sanitary Districts with water works (ESD) that were proposed by the Thai government for study.

(1) New Sanitary District (NSD)

(a) First Phase

Code No.	SD Name	Changwat	Amphoe
2	Rong Kham	Kalasin	Kamalasai
5	Kham Sakae Sang	Nakhon Ratchasima	Kham Sakae Sang
6	Nong Bua Lai	Nakhon Ratchasima	Bua Yai
7	Huai Thaleng	Nakhon Ratchasima	Huai Thaleng
8	Nong Ki	Buriram	Nong Ki
9	Hin Lek Fai	Buriram	Khu Muang
10	Huai Rat	Buriram	Huai Rat
11	Sai Mun	Yasothon	Muang
12	Khun Han	Si Sa Ket	Khun Han
13	Kusman	Sakon Nakhon	Kusman
15	Don Khuang	Sakon Nakhon	Sawang Daen Din
17	Phon Charoen	Nong Khai	Phon Charoen
18	Nong Song Hong	Nong Khai	Nong Song Hong
20	Huai Kha Yung	Ubon Ratchathani	Warin Chamrap

(b) Second Phase

The ten NSD to be studied in the second phase were selected in accordance with the results of the first phase pre-feasibility study. The names of the deleted projects are Rong Kham (NSD 2), Hin Lek Fai (NSD 9), Sai Mun (NSD 11) and Don Khuang (NSD 15) Sanitary Districts.

(2) Existing Sanitary District (ESD)

Code No.	SD Name	Changwat	Amphoe
1	Cho Ho	Nokhon Ratchasima	Muang
2	Non Thai	Nokhon Ratchasima	Non Thai
3	Prang Ku	Si Sa Ket	Prang Ku
4	Tha Kae	Sakon Nakhon	Muang
5	Akat Amnuai	Sakon Nakhon	Akat Amnuai
6	Sankha	Surin	Sankha
7	Ban Phu	Udon Thani	Ban Phu
8	Khuang Nai	Udon Ratchathani	Khuang Nai
9	Chanuman	Udon Ratchathani	Chanuman
10	Khamcha-i	Mukdaha	Khamcha-i

CHAPTER II. REGIONAL ADMINISTRATION

CHAPTER II. REGIONAL ADMINISTRATION

2.1. Local Government and Regional Administration

2.1.1. Structure of Local State Government

The local governments of Thailand consist of Provinces (Changwat), Districts (Amphoe), Communes (Tambol) and Villages (Muban).

The provincial government is a primary unit of territorial administration and is a local state government because it is a hierarchical unit administered and staffed under the system of deconcentration by the national government. Most of the required funds are provided by the national government.

The administration of a province is under the authority and responsibility of a governor. The governor is assisted by one or two vice-governors. The governor and his assistants, appointed by the Minister of Interior, are government officials of the Ministry of Interior. There are now 73 provinces including the Bangkok Metropolis in the country.

Each province is divided into districts which are headed by district officers (Nai Amphoe), who are the government officials appointed by the Ministry of Interior through the Department of Local Administration. They have the responsibility for the district administration, assisted by deputy district officers, and are also officials of the Ministry of Interior.

There are also government officials working in the districts who represent the various ministries such as Ministry of Education, Ministry of Public Health, Ministry of Agriculture and Cooperative, Ministry of Finance, etc. and try to meet the requirements of the district. There are now 616 districts, some of which are further divided into sub-districts (King Amphoe) of 83.

In general, a district is divided into communes (Tambol) and villages (Muban). A commune is headed by a commune headman (Kamnan) and a village is headed by village headman (Poo Yaiban). They are elected by inhabitants within their territory, however they are under the direction and control of the district officer.

The commune headman is assisted by a deputy who is chosen by the commune headman with the approval of the district officer and the provincial governor. The village headman has the similar duty and function as those of the commune headman. He is assisted by two assistants chosen by himself and approved by the commune headman and the district officer. There are 6184 communes and 55,772 villages now in Thailand.

2.1.2. Unit of Local Self Government

The local autonomy is characterized by the concept of decentralization and is organized as follows:

- Provincial Administration Authority
- Municipal Government
- Sanitary District
- Special Local Self Government Units
- Bangkok Metropolitan Administration
- City of Pattaya

(1) Provincial Administration Authority

The provincial administration authority is composed of two bodies; one is the legislative body and the other is the executive body.

A provincial council is the legislative body. It is composed of 18 to 36 members depending upon the number of the people in the province. The council members are elected from every district in the province by five year term. The regular session is held once a year for a period of not more than thirty days.

The executive body of authority is the governor of the province. There are several divisions and sections under the supervision of the governor, which are determined by the authority. The major powers and duties of the governor will be:

- Providing clean water, markets, ports, ferries, cemetery ground and crematories
- Promoting occupations for local inhabitants
- Providing and maintaining medical services
- Providing and maintaining electric works or other lighting facilities.

To administer all of these functions, the authority is allowed to make a budget allocation and also allowed to collect revenue such as taxes and fees, income from provincial property, loans, grants-in-aid, donation and others as specified by law.

(2) Municipal Government

The municipal government (Tesaban) is one of the local self governments, which is headed by a Mayor with some assistants and an assembly. There are 123 municipal governments established now in the urban areas.

The municipal governments are divided into following three classes; such as city municipal (Tesaban Nakorn), town municipal (Tesaban Muang), and commune municipal (Tesaban Tambol). The class of the municipal is determined by total population and population density in the relevant area and the amount of tax revenue available for the self government. A municipal government must set up required facilities in each area where the provincial administration office is located.

The mayor and his assistants must be members of the municipal assembly who are elected by the local people. They have the power to determine the policy and administration of municipal area. The head and clerks of a department are the municipal employees.

A municipal assembly is composed of members varying in number. For example, a city municipal assembly has twenty-four members while that of a town has eighteen and a commune has twelve respectively. Assembly members are elected by the local people by five-year term. The primary functions of an assembly are to enact the by-laws, to approve the municipal budget and to control the executives in the administration.

The problem is that there are many compulsory and optional functions/duties of the municipal government with low revenue and budget. The revenue sources of the municipal government are almost in the same categories as those of the provincial government.

(3) Sanitary District (SD)

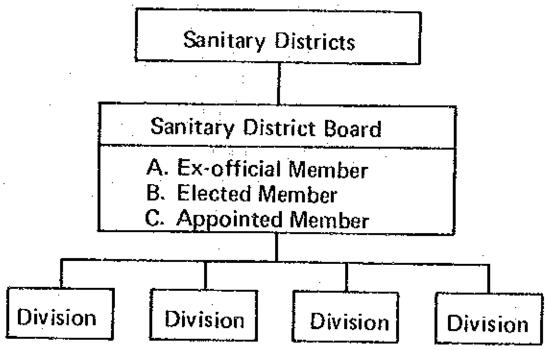
A Sanitary District will be established, enlarged, reduced or eliminated by the orders of the Ministry of Interior. Sanitary Districts have been developed with some historical background since the formation of the Bangkok Sanitary District, which was established in 1897. The organization, major duties and functions of a SD are discussed in the next section.

2.2. Organization and Functions of Sanitary District

2.2.1. Organization of Sanitary District

Unlike a Changwat and Municipality, the organization of a SD is not separated into legislative and executive arms. The administration of a SD is under the responsibility of the SD Board composed of members who represent following three categories.

- Ex-Official members: District Officer, District Chief of Police, District Public Health Officer, District Treasury Officer, all of the commune and village headmen.
- Appointed member: one of Deputy District Officers acting as SD Clerk (administrative chief).
- Elected members: Four qualified villagers elected directly from the local people and serve for four-year term.



2.2.2. Function and Revenue/Budget Procedure

(1) Function

The functions of a SD as referred to in the Sanitary District Act of 1952 are given below:

- Provide and maintain roads and waterways
- Provide and maintain drainage system

- Keep roads, sidewalks and public places clean
- Refuse and garbage disposal
- Prevent and suppress communicable diseases
- Provide clean water or water supply
- Provide slaughterhouse
- Provide market, ferry and harbour facilities
- Provide cemeteries and crematoria
- Provide and maintain electricity or other lighting facilities
- Prevent and relieve natural disasters
- Provide fire fighting equipment
- Provide and maintain medical centres
- Promote people's education
- Provide and promote people's employment
- Provide and maintain sport, recreation facilities, public parks, zoos and people's meeting places
- Promote movements for extending religion, culture and ethics.
- Provide necessary public utilities
- Promote commercial activities
- Promote other necessary Sanitary District activities for the benefit of people or duties stated by law.

(2) Revenue and Budgeting Procedure

To perform all of these functions, a SD has the following sources of revenue in accordance with the Sanitary District Revenue Act of 1955:

- House and land taxes
- Animal slaughtering tax
- Signboard tax
- Local development tax
- Supplementary taxes and fees at a rate of not more than 10 percent of all or some of the following:
  - Business Tax
  - Commodity purchase tax

- Liquor tax
- Liquor sale licence fee
- Gambling licence fee
- Beverage tax
- Entertainment tax

- 25 percent of the motor vehicle and wheel conveyance taxes and fees
- 50 percent of the municipal development tax
- Subsidy from the national budget

A SD's budgeting procedure is shown below:

<u>District Officer and SD Clerk</u>

↓ request for submission of the estimated budget for next fiscal year.

<u>Sectoral Divisions</u>

↓ submission of the budget proposals

<u>SD Clerk</u>

↓ submission of the budget proposals

<u>SD Board</u>

↓ submission for the final approval and signature

<u>Changwat Governor</u>

(3) Special Issue

The SD Board, chaired by the District Officer, is authorized to control and take responsibilities as stipulated in the Sanitary District Act. The Board has power to enact the Sanitary District ordinances to comply with its function or as stated by the Act. A meeting is held at least once a month to deliberate its activities.

The Changwat Governor has the authority to control and supervise the SD. He can withdraw or discontinue the activities which are against the law, or public peace and order. He has also the power to suggest, recommend, investigate and interrogate documents and personnel of the SD Board.

2.3. Agencies Concerned with Waterworks Project

2.3.1. Urban Water Supply Agencies

(1) Metropolitan Waterworks Authority (MWWA)

Bangkok Metropolitan water supply is under the full responsibility of MWWA which is a state enterprise established in 1967.

(2) Provincial Waterworks Authority (PWA)

PWA is responsible for public water supply serving some of the Municipalities and Sanitary Districts. PWA which is a state enterprise was established in 1979 with integration of divisions of the Provincial Water Supply Division of PWD and the Rural Water Supply Division of Department of Health (DH).

(3) Department of Public Works (PWD)

Provincial Water Supply Division (PWSD) was established under the name of Plumbing Division in 1933 as one of the centralized divisions of PWD which belongs to the Ministry of Interior, with the Primary functions to develop and carry out the general waterworks system of the country.

As introduced in para. 2.1, PWSD has the responsibility for implementation and regulation of the following two tasks after the establishment of PWA in 1979:

- To survey, design and control the waterworks owned by Municipalities, Sanitary Districts and private sector, including the examination and renewal of permit and concession issuances in accordance with the Revolutionary Party Order No.58; and,
- To survey and design the waterworks system for the governmental agencies as requested.

2.3.2. Rural Water Supply Agencies

Sixteen (16) governmental agencies under six ministries are listed in the Table E-2-2 in Appendix E, and they are responsible for a rural water supply scheme. A small-scale water resources are generally developed to include water for agricultural, fishery and livestock use as well as for household use.

Of the sixteen agencies, only twelve agencies are responsible for the provision of water supply for drinking and domestic consumption in addition to the agricultural water use. The services of another four agencies are confined to the specific project sites under the jurisdiction of their authorities. Consequently, eight agencies are engaged directly in the rural water supply services for drinking and domestic consumption throughout the Kingdom.

PWSD, which is a counterpart and also an executing agency for the subject project study, is one of the major execution agencies of rural water supply projects. PWSD is divided into four subdivisions, being Administration, Technical and Planning, Waterwork System Development and Deep Well Drilling Work Subdivisions. The total number of the PWSD officials is 373, in which 31 civil engineers and 81 civil technicians are included. It seems that such manpower would be sufficient enough to carry out the development of programs and projects at the present budget allocation level.

2.4. Government's Development Policy of Waterworks Sector

2.4.1. Decentralization and Urbanization of Sanitary Districts

The Fifth Five-Year Plan (1982 - 1986) has proposed a development strategy that would shift the emphasis of development from large urban areas to rural ones. This would diffuse the effects of growth by decentralizing the economic activities to the rural regions, thus giving the larger cities a reprieve from uncontrollable population growth.

An effort has been made to establish and develop regional urban growth centers and sub-centers in all the regions so as to promote the structural adjustment program in agricultural and industrial decentralization, as well as to bring about a better balanced growth in the "Urban System" in the future. This is made in conjunction with a plan to develop the Bangkok Metropolis.

This decentralization effort will be necessary since the forecasted population growth for large urban centers during the next ten years, will be accelerated at a much higher rate. Without proper planning, it is clear that there will be mass migration to the Bangkok Metropolis, which would cause problems of congestion and deterioration of the city, far more serious than experienced to date.

The Fifth Five-Year Plan intends that such economic bases as regional urban growth centers and sub-centers will serve as employment generation centers so that the export-oriented industries, commercial activities and other small-scale services industries can be actively assisted. Agricultural activities surrounding the regional centers will also be encouraged. With this development concept, it is expected that the urban activities in the regional urban growth centers or namely, Sanitary Districts, which will have a characteristic as in-between "Urban" and "Rural" will be encouraged to grow vigorously in future. In concurrence with this growth, the related water supply services should be properly improved to promote the urban activities as mentioned above.

2.4.2. Development Policy of Waterworks and Its Assessment

It is a common observation that among villagers, rainwater ranks high in their preference for drinking water since the taste is of primary importance to them. This is not a problem during the rainy season, but during the dry season, the local people have to use other sources for drinking purpose. Shallow wells or ponds are the preferred sources in such circumstances, but these often dry up, and the people are forced to walk a long way to get water. This well water is also often found to be unsafe. Taking into account this habit of water use by rural people, it can be observed that a majority of the masses, including those in the Sanitary Districts without waterworks, can not obtain safe drinking water. The original program objectives, as expressed in the 1964 Cabinet Resolution, of helping to prevent diseases by providing adequate and safe water for consumption on a year-round basis have not yet been achieved.

On the other hand, it appears that the sanitation is much less of a problem for the people than the water supply. The Department of Health reported in 1981 that there were about 2.6 million pour-flush latrines installed throughout the country, serving 41 percent of the total number of households outside Municipalities. In addition, provisions have also been made for biogas digesters as early as 1971, and for double-vault composting pour-flush latrines in the current development plan.

It should be emphasized that one of the overall development objectives of the Thai Government is the raising of the quality of life for the rural population, and one relevant means to achieve this goal is the improvement of public health through the provision of a safe water supply and sanitation services. Vigorous efforts have been made in the past to extend these basic services; however, a considerable number of households still lack access to clean water and toilet facilities, and this situation exposes them to a wide range of water-borne and related diseases which can limit their economic productivity.

Definite such efforts of the Thai Government, with respect to the provision of water supply and sanitation services to the rural population, have been outlined by the standing policy proposed in the current economic plan. By the time the Fifth Five-Year Plan (September, 1986) is completed, 95 percent of the rural population should have access to an adequate and evenly distributed potable and domestic water supply, and that 70 percent of the rural households should be installed with pour-flush latrines.

The preliminary study report on the Immediate Improvement and Construction of Sanitary District Waterworks Project (ICSDP) prepared by PWSD in February 1982 clearly states that the major objectives are to upgrade the standard and quality of living of the people in the Sanitary Districts in accordance with the Government policy. It is recognized that this is one of the approaches in connection with the achievement of the Government's planned policies as introduced above.

The ICSDP, which promotes the efficient and substantial provision of adequate potable water supply services for the six million people living in the Sanitary Districts throughout the country, expected the following additional benefits:

- To speed up the improvement of socio-economic conditions through the provision of basic infrastructure, in the Sanitary Districts, which are expected to grow as the regional urban centers in future;
- To eliminate migration of people from Sanitary Districts to urban areas and thus to control urban problems; and,
- To improve the community sanitation, and thus increase the hygienic and health benefits for the people in the Sanitary Districts.

In line with the above-mentioned sector policies, the Thai Government has taken up this subject Project as the first step to examine and assess the technical and economic feasibility for improvement and development of the Sanitary District Waterworks in the Northeastern Region. This takes into account the various factors involved such as the high degree of water scarcity, as well as, the promotion of security and political stability.

CHAPTER III. PROJECT AREA

CHAPTER III. PROJECT AREA

3.1. General Features of Northeastern Region

3.1.1. General Features

The main geographical feature of the Northeastern region is a high plateau known as "Khorat Plateau" being about 100 to 200 m above sea level. This vast plateau is separated from the central plain and also an isolated part of the country by the Phetchabun range, the Dong Phaya Yen range and the Phanom Dong Rak range. The landscape is sloping from west to east towards the Mae Khong river which is the natural border line of Thailand and Lao People's Democratic Republic. The total area of the Northeastern region comprising 17 provinces (Changwat), is about 170,000 sq.km or 32.9 percent of the total land area of the country. The regional population was 12.8 million in 1970, and 15.1 million in 1976, and increased to 16.7 million in 1982 or 34.2 percent of the nation.

The Northeastern region has usually been regarded as the problem area of the Kingdom with a backward economy, low per capita income, limited transport facilities and other factors such as irregular distribution of rainwater, poor soils and severe weather which are all obstacles to economic and social development.

On the alluvial plains and the lower parts of lower terraces in the Northeastern region, most of the original forests have been removed and the land is used for growing transplanted paddy. In these areas, the paddy fields are flooded by impounded rainwater being largely dependent upon unreliable rainfall during the wet season, and only one crop per year can be grown. In some areas, irrigation water is used either from dams or tanks, but the total area of irrigated land is very small. Available information has identified that people in the Northeastern rural area work in the field only less than 200 days per year. After the wet paddy harvesting, a large number of the rural people migrate to various cities or areas in order to get a job or to seek job opportunities. This also creates the socio-economic problems not only in the Northeast, but in the Kingdom.

In a broad view, the improvement of conditions in the Northeastern agricultural sector, which includes about 77 percent of the population of the Northeastern region and 38 percent of the gross domestic product in 1982, is very complicated from a long-term view. Although much remains to be done, the existing development programs are making gradual progress and slowly influencing the rural communities. It can be summarized that the natural state of the Northeastern region is in generally full of disadvantages and, though it is possible to survive, the rapid progress toward general well-being of the population requires a substantial monetary investment. This investment should place a particular emphasis upon water control and basic social infrastructure, which could lead to science-based agriculture, thus eradicating severe poverty.

3.1.2. Meteorology and Hydrology

The Northeastern region is subject to the tropical monsoon climate in the Southeast Asia. The Southwest monsoon (mid-May to September) flows out of the Indian Ocean often with heavy rains, while the Northeast monsoon (November to February) from the mainland China creates an extended dry spell. Two transitional periods are called the retreating Southwest monsoon period in October (cool) and the retreating Northeast monsoon period in March to May (hot).

The Southeast monsoon carries moisture-laden air northeastward towards and across the Khorat Plateau. It does not bring continuous rain to the region. The monsoon rainfall consists primarily of the localized shower with the frequency, concentration and intensity dependent upon time and the month and the year of its season.

Attention should be paid to the dry periods which frequently occur in June or July normally lasting 15 to 20 days. It has been said that the Lower Northeastern region has often suffered from the influence of heavy rainfall originated from the typhoon.

The meteorological data that has been collected at five representative sites in the region for 30 years (1951 to 1980) are summarized in Appendix A.1. The average annual rainfall in this region, ranges from 1,800 mm in the northeastern part of this region, to 1,100 mm in the southeastern part near Nakhon Ratchasima. This is as high as in other regions, but it is unevenly distributed throughout the year. Since the soil can not conserve such a large amount of water and humidity, about 80 percent of the total rainfall during the high peak period, normally in late August to early September, always quickly flows down to the Mae Khong River.

The major surface water resources of the Northeastern region are the Mun and Chi Rivers which originate in the watershed area in Changwat Nakhon Ratchasima and Chaiyaphum. Besides, there are some other rivers scattering in the region, viz. Loei River, Song Kham River, Don River, and so forth. Most of them flow through the central lowland of the region and then downward to the Mae Khong River. The fluctuation of the river discharges between the rainy and the dry seasons is considerably large, and the rivers with less drainage area are completely dry up in the dry season.

3.1.3. Society and Economy

The primary function of the urban centers of the Northeastern region is to provide trade and service facilities to the areas surrounding them. Many of the larger urban centers such as Khorat, Khon Kaen, Ubon and Udon are also the traditional seat of administration at the Changwat level. Before the advent of modern communication, each urban center enjoyed continuous growth according to the pace of natural population increase, immune from new competition from other centers by the sheer physical distance separating them.

Early in this century, the railway system in the Northeast was built with Khorat at the southwestern corner as the junction of two branches running to the railhead for one of the branches and the eastern apex of Udon for the other. The railway has enabled the three major centers to extend their sphere of influence, and eventually to the respective major centers. This trend is particularly favourable to Nakhon Ratchasima, the focal point of rail network, as its traditional gateway role has become further emphasized.

The other revolutionary change in the field of urban development in this region was brought about by the construction of the Friendship Highway linking both Udon Thani, and linking Ubon Ratchathani with Nakhon Ratchasima . This road network development was extended to Sakon Nakhon. The Khon Kaen - Chumphae Road was also constructed, allowing the trade of Loei and Chaiyaphum and also provides an alternative route to the central plain via Lom Sak.

The latest phase of urban development in the Northeastern region was the establishment of sizeable air ports. A large number of people got the opportunity for employment, and therefore, the construction work was provided by the public and private sectors. The increased efficiency of communication and transportation systems has enabled both the traders and retailers in various parts of the region to draw their supplies directly from Bangkok and thereby helping the capital city to penetrate deeply into the hinterland of the three major secondary cities of the region.

The development of the Northeastern region for the last decades has achieved an expansion in every economic sector, especially agriculture, industry, transportation, commerce and services.

Consequently, the per capita Gross Regional Product (GRP) has increased 5.9 times, rising from ฿1,082 in 1960 to ฿6,390 in 1982. However, the Northeastern region's share of the GDP, which was 17.0 percent of the Gross Domestic Product (GDP) in 1960, declined to 12.8 percent in 1982. This is primarily because the agricultural sector's output, which was the main source of economic production of the region, accounting for half of the GRP in 1975 was generated by the expansion of agricultural land. Recently there has been no room for further expansion in the region. Infertile and marginal land has been resorted but result in low yields. It is, therefore, necessary to develop this low yielding agricultural area as well as those areas with deteriorating natural resources.

Structure of the 1982 GDP at current price is summarized in Table 3-1-1, in comparison with that of the whole Kingdom.

Table 3-1-1 Gross Ragional Product in the Northeast
- at 1982 current prices -

(Unit: million of Baht)

Industrial Origin	Northeastern Region Product	Northeastern Region %	Whole Kingdom Product	Whole Kingdom %
1. Agriculture	38,561	35.2	177,152	20.6
- Crops	29,389	26.8	129,825	15.1
- Livestocks	6,949	6.3	22,227	2.6
- Fisheries	1,219	1.1	13,544	1.6
- Forestry	1,004	0.9	11,556	1.3
2. Mining and Quarrying	820	0.7	15,703	1.8
3. Manufacturing	8,807	8.0	177,147	20.6
4. Construction	6,447	5.9	44,821	5.2
5. Electricity and Water Supply	975	0.9	12,353	1.4
6. Transportation and Communication	7,719	7.0	68,683	8.0
7. Wholesale and Retail Trade	21,822	19.9	167,605	19.5
8. Banking Insurance and Real Estate	3,192	2.9	61,182	7.1
9. Ownership of Dwellings	1,092	1.0	9,874	1.2
10. Public Administration and Defense	7,960	7.3	37,032	4.3
11. Services	12,209	11.2	86,819	10.2
Total (GRP and GDP)	109,604 (12.8)*	100.0	858,371	100.0
Per Capita GRP and GDP (Unit: Baht)	6,390 (36.1)*		17,702	

Note: * ... Whole Kingdom = 100

3.2. Subject Project Area

3.2.1. Social Background

It has been observed in the field that the SD is generally under developed as the socio-economic core of the surrounding rural areas. There are several public facilities such as schools, sanitation centers, police stations and temples located within the SD which seems to contribute to the rural people for improving their welfare, sanitation, education and safety, and so on. Also the SD is playing an important role as the center for marketing of various commodities for the surrounding rural areas, but the activities by private commercial/manufacturing enterprises are rather few.

Farm households in the said 14 SDs account for more than half of the total, having an annual income per household of ฿10,000 to ฿60,000. There is uneven distribution of income; therefore, it can be said that in the SD with the agriculture-oriented development area in its vicinity, the scale of economic activities would be one of the key factors in providing waterworks in the related SD area.

The information of the subject project is summarized in Table 3-2-1.

3.2.2. Domestic Water Supply

Rain water is the major source of the drinking water in most of the SDs. Each and every household has its own jar for storing rain water. The big jars can store the water more than 3.0 cu.m, and the households earning the higher income have a several number of such jars. Through each districts sanitation center, the Department of Health has been promoting the use of rain water, stored in jars for drinking purposes, instead of water taken from shallow wells or ponds. There is also a campaign which has been undertaken for upgrading the quality of drinking water through the proper guidance in the sanitary preservation of drinking water in jars. The reasons backing up the campaign can be briefly referred to as follows.

- For those SDs, where the population have increased remarkably, raw water derived from shallow wells is getting seriously polluted. Toilets have not been popularized and there is no treatment made on the domestic water after use, therefore, the use of polluted raw water is not favorable.

- People have a preference for rain water for drinking.

Where there is no shallow well available, people have to carry their water from the neighbouring rivers and/or ponds for a distance of anywhere between 500 and 2,000 m. Sometimes, there are the cases of water transportation by a specialized carrier, that charge a fee ranging from ฿5 to ฿25 per 200 liters.

3.2.3. Sanitary Conditions

(1) Sanitary Environment

The Department of Health takes the administrative responsibilities of sanitary environment conservation for each SD. There are nine Sanitary Region Centers in the whole Thailand. In the Northeastern region of Thailand, No.3 Center (Nakhon Ratchasima) and No.4 Center (Khon Kaen) are providing the sanitation service.

(a) Human Waste Disposal

The installation ratio of water closets in ESDs is 54 percent and in NSDs, 50 percent; that is, the former is a little higher. A vacuum car dispatched by the nearest municipalities, rotates to the local districts for collecting wastes sludge once a year. A final disposal plant in the Northeastern region is located in Udon Thani. Waste sludge carried to the plant are kept there for about one month to be used as fertilizer.

(b) Waste Disposal

There are individual or public waste boxes for collecting fecal waste on the roadside. The waste collectors, with manpower-drawn cars with some additional workers, collect, wastes and put them in a dumping site in the SD to be burnt or leave them as they are. According to the data, the SDs do not have even a simplified incinerator.

(c) Drainage of Individual Houses

Individual houses discharge waste water to the fields in SD through a sewerage pipe (400 m/m - 600 m/m in diameter) installed under the road or in the road ditches. There are six NSDs that discharge waste water to a river.

(d) Cleaning in SDs

Cleaning in the SDs is made by disinfecting the waste boxes after the waste is collected by workers.

(e) Insect Control

Insect control in the SDs has been made by spraying pesticide before the rainy season. Every SD, however, has not practiced such insect control. Three of the 14 SDs have not practiced the services during the year, whereas, three SDs have practiced it over two times a year.

(2) Water-borne Diseases

The interview survey on the occurrence of water-borne and water-related diseases in the SDs was conducted at the Health Center of each SD. The disease occurrence frequency was studied on the basis of the data available in Amphoe. The data are only available for the last year or two. As the result of this investigation, it was found that the number of cases of diarrhea is incessant. The number of cases of Enteric Fever, Hepatitis, Typhoid Fever and Scrub Typhus are shown in Table 3-2-2.

(3) Public Health

According to the Fifth Five-Year Plan, one public hospital will be constructed in each Amphoe until 1986. As for NSDs, most of Amphoe have hospitals except Rong Kham (NSD-2) in which a hospital is under construction. In the ESDs, every Amphoe has a hospital including Non Thai (ESD-3) where construction has been completed to await the commencement of activities. The health centers which are staffed by a public midwives and of health nurses give medical consultation to pregnant women and teach guidelines health, sanitation.

3.2.4. Socio-economic Conditions

(1) Area of Agricultural Land Around SDs

In comparison with the other regions, the Northeastern region shows a higher ratio of reliance on agriculture in the local economy. Table 3-2-3, shows the total GRP for the Northeastern region and the GPP for each Changwat related to the subject project. According to the table, agriculture forms 35 percent of the GRP on an average, and as a whole, if industries in relation to agriculture, including production and processing such as seeds, fertilizer, agricultural chemicals, rice milling and others, are included, the ratio would be much higher. Also the size of industry indicates the scale of employment. Most of the inhabitants in the Project Area are directly or indirectly engaged in agriculture. The size of the agricultural zone was utilized to determine the degree of economic activity around each SD. A topographical map of 1:50,000 scale was used to measure the acreage of agricultural land, mainly for paddy fields in a radius of 5.0 km from the center of the SD. The acreage of agricultural land per person was also calculated on the basis of comparing the population of each SD and with the area of agricultural land concerned.

(2) Distance between SD and Main Road (Marketing Condition)

The economic activity in the SD will be expanded and developed by the expanding agricultural developments in the peripheral rural areas. The arrangement of the road access will be indispensable for smooth transportation of agricultural inputs from urban areas to the rural areas and outputs from the farms to the markets.

Table 3-2-1 General Condition of the Project Area

Description	Unit	NSD-5 Kham Sakae Sang	NSD-6 Nong Bua Lai	NSD-7 Huai Thalaeng	NSD-8 Nong Ki	NSD-10 Huai Rat	NSD-12 Khun Han	NSD-13 Kusuman	NSD-17 Phon Charoen	NSD-18 Nong Song Hong	NSD-20 Huai Khayung
1. Location											
- Amphoe		Kham Sakae Sang	Bua Yai	Huai Thalaeng	Nong Ki	Muang Buri Ran	Khun Han	Kusuman	Phon Charoen	Nong Song Hong	Warin Chamrap
- Changwat		Nakhon Ratchasima	Nakhon Ratchasima	Nakhon Ratchasima	Buri Ran	Buri Ran	Si Sa Ket	Sakon Nakhon	Nong Khai	Nong Khai	Ubon Ratchathani
2. Establishment of SD		1972	1964	1962	1969	1962	1956	1973	1981	1982	1956
3. Area and Population (1984)											
- Proposed Area	km^2	2.00	3.03	2.62	5.40	1.73	2.2 (12.00)	4.00	10.00	4.53	2.80
- Total Population	Persons	4,816	3,314	9,598	13,100	3,785	3,139 (8,111)	5,248	9,697	7,914	3,813
- Agricultural	"	3,227	1,756	4,511	7,991	2,233	1,836 (4,743)	4,041	-	-	2,326
- Non Agricultural	"	1,589	1,558	5,087	5,109	1,552	1,303 (3,368)	1,207	-	-	1,487
- Population Density	Persons/km^2	2,408	1,094	3,658	2,425	2,194	1,427 (676)	1,371	970	1,747	1,362
- Nos., of Household	Household	633	451	1,100	1,912	457	920 (1,380)	781	1,448	951	569
- Nos., of Muban	Nos.	3	4	3	12	3	1 (7)	2	8	5	4
4. Social Infrastructure											
- Health Center	Nos.	1	1	-	-	1	-	1	1	1	1
- Other Government Office	"	4	3	5	10	3	6	5	3	3	3
- Temple	"	1	-	1	2	1	6	2	3	2	1
- Hotel	"	-	-	-	1	-	-	-	-	-	-
- Big Factory	"	Rice mill	Rice mill	Rice mill	Rice mill	Rice mill	Rice mill	Rice mill	Rice mill	Rice mill	Rice mill
- Market	shops	70-80	60±	130-140	100±	50	80±	40±	80±	150±	160±

Note: Figures in the parenthesis means the total of the sanitary district

Table 3-2-2 Water-Borne and Water-Related Disease in 1983/84

	N.S.D.	Population	Disease No.	Disease Percent
2.	Rong Kham	4,886	11 1/	0.23
5.	Khan Sakae Sang	4,816	25	0.52
6.	Nong Bua Lai	3,314	33	1.00
7.	Huai Thalaeng	9,598	59	0.61
8.	Nong Ki	13,100	109 1/	0.83
9.	Hin Lek Fai	5,086	28	0.55
10.	Huai Rat	3,785	32	0.85
11.	Sai Mun	6,087	78	1.28
12.	Khun Han	4,178	6	0.14
13.	Kusuman	5,248	72 1/	1.37
15.	Dong Khuang	13,460	N.A.	-
17.	Phon Charoen	9,697	27	0.28
18.	Nong Song Hong	7,914	20	0.25
20.	Huai Kha Yung	3,813	112 2/	2.94
	Total	94,982	612	0.64

Note: 1/ ... Estimated from the Data of Public Health Center and Offices of Amphoe and Tambon in terms of population.

2/ ... Including food poisoning.

Table 3-2-3 Gross Provincial Product of Each Changwat in the Northeast
- at 1982 current prices -

(Unit: Million of Baht)

Changwat	GPP	Agriculture	Percent
A. Northeastern Region			
1. Kalasin	4,257	1,786	42.0
2. Khon Kaen	11,462	2,823	24.6
3. Chaiyaphum	5,435	2,256	41.5
4. Nakhon Phanom	4,621	1,657	35.9
5. Nakhon Ratchasima	16,074	4,996	31.1
6. Buri Ram	6,364	2,588	40.7
7. Maha Sarakham	4,541	1,713	37.7
8. Yasothon	2,735	981	35.9
9. Roi Et	5,848	2,051	35.1
10. Loei	4,040	1,719	42.5
11. Si Sa Ket	5,733	2,210	38.5
12. Sahon Nakhon	5,248	1,913	36.5
13. Surin	5,800	1,946	33.6
14. Nong Khai	4,757	1,876	39.4
15. Udon Thani	12,538	4,856	38.7
16. Ubon Ratchathani	10,151	3,190	31.4
Total (GRP)	109,604	38,561	35.2
B. Whole Kingdom (GDP)	858,371	177,152	20.6

Source: NESDB

3.3. Review of Existing Sanitary District Waterworks

3.3.1. Water Demand and Service Level

(1) Water Demand

(a) Average Daily Water Consumption

In planning the new water supply works, actual water consumption in the existing Sanitary Districts is estimated through the process of a reverse operation using the yearly water charge collected as the starting data.

$$DWCC = (WC - BC \times 12 \times NM)/(MR \times PS \times 365) \times 1{,}000$$

Where, DWCC = average daily water consumption per capita (lcd)
WC = yearly water charge collected (฿/yr.)
BC = basic rate of water charge (฿/month)
NW = number of water meters installed
MR = meter rate of water charge (฿/cu.m)
PS = population served

According to the analyzed data in the Table A-2-1 in Appendix A, the consumption of water in the ESDs ranges widely from 35 lcd to 106 lcd with 65 lcd being the average.

The average daily water consumption per capita discussed above is the amount of water effectively consumed excluding wastage and leakage losses.

The average daily water demand in different scale waterworks is shown in Table 3-3-1.

The demand of the small scale concessional waterworks fluctuates from 108 lcd to 139 lcd with 120 lcd being the average. These figures would include the volume of leakage/wastage, which is equivalent to about 50 percent of the total as shown in Table A-2-2 in Appendix A. Therefore, the daily water consumption per capita, excluding leakage/wastage, of the small scale concessional waterworks, is more or less 60 lcd.

The consumers have used the water supplied from some existing waterworks under the following circumstances.

- The water is supplied in the limited operation time of 2 to 8 hours per day.
- Rain water is still willingly used.
- Some consumers have alternative water sources such as shallow wells.

Therefore, the figures quoted above are rather conservative as compared with the total water consumption.

Table 3-3-1. Rate of Service and Water Demand in 1983

Water Works	Population	Rate of Service	Pop. Served	Average Consumption cu.m/y	Average Consumption lcd
	a	b	c	d	d/c/365x 1,000
1. Large Scale					
- Phitsanulok	72,839	97	70,654	3,986,593	155
- Nakhon Rachasima	191,462	32	61,268	7,726,282	345
Average	132,151	65	65,961	5,856,438	243
2. Medium Scale					
- Uthai Thani	17,487	90	15,738	805,391	140
- Ayuttaya	55,301	68	37,605	2,052,835	150
- Saraburi	48,669	60	29,201	1,565,939	147
- Phuket	45,917	44	20,203	2,225,294	302
- Ratburi	44,979	61	27,437	2,403,162	240
- Uttaradit	31,699	59	18,702	812,035	119
- Hua Hin	32,017	54	17,289	1,006,309	159
Average	39,438	62	23,739	1,552,995	179
3. Small Scale					
- Potharam	10,881	80	8,705	441,581	139
- Chum Sang	13,950	48	6,696	272,941	112
- Nong Kae	11,668	53	6,184	244,851	108
- Kratumban	12,446	94	11,699	499,000	117
Average	12,236	69	8,321	364,593	120

Note: The definition of scale is determined by the number of water meters tentatively in use. (Large scale = More than 8,000, Medium scale = 2,000 to 8,000, Small scale = Less than 2,000)

(b) Average Daily Water Demand

The average daily water demand is defined as the water consumption, which consists of domestic, commercial, public and industrial users, and includes leakage and wastage in the water supply systems.

As indicated in Table 3-3-1, an average demand of 120 lcd is the average value by the small scale rural waterworks with served population ranging 6,000 to 12,000.

(2) Service Rate and Level

The service rate of ten ESD waterworks ranges from 18 to 56 percent of the total population with 36 percent on an average in 1984 as tabulated in Table 3-3-2. Major reasons of such a low rate are limited installation of distribution pipeline networks within the existing Sanitary District areas, due to a lack in the construction budget for expansion works and the traditional utilization of rainwater.

The service level by terminal waterworks system is mostly at the house connection.

Table 3-3-2. Rate of Service and Population Served in the ESD Studied

ESD		1983		1984	
Code No.	ESD Name	R.S.	P.S.	R.S.	P.S.
1	Cho Ho	N.A	N.A	52	5,974
2	Non Thai	25	1,293	38	1,865
3	Prang Ku	18	436	18	436
4	Tha Rae	24	2,205	N.A	N.A
5	Akat Amnuai	32	2,669	33	2,861
6	Sankha	40	2,141	56	2,944
7	Ban Phu	38	1,883	38	2,500
8	Khuang Nai	24	1,341	24	1,347
9	Chanuman	48	1,636	40	1,417
10	Khamcha-i	N.A	N.A	24	541
	Means	31		36	

Note: R.S.: Rate of Service
P.S.: Population Served
N.A.: Not Available

3.3.2. Major Water Sources

(1) Water Sources

In a field survey of the ESDs, the major water sources which are commonly used for existing waterworks were found to be rivers, lakes, ponds, reservoirs and deep wells as shown in Table A-5-1 in Appendix A. It is concluded that the reservoirs, which were constructed by RID for the purpose of an irrigation water supply, are reliable water sources in both water quantity and quality, unlike the natural ponds and deep wells. This is because these natural ponds have rather small catchment areas and some of the deep wells in the area have no stable quantity of water during the dry season and have a high alkalinity content, even during the rainy season.

In order to solve the aforesaid major problems the Sanitary Districts concerned have a plan to convert the existing natural water sources to more stable and dependable ones as shown in Table A-3-1.

(2) Raw Water Quality

The results of raw water quality analysis of the sources of water for both the existing and the proposed waterworks in the Sanitary Districts are tabulated in Table A-5-3 to A-5-5, respectively. The analysis of raw water was carried out by field test, laboratory tests, and jar tests in the course of the field survey.

The analysis of the water samples tested has revealed that with some exceptions the tested water is lower in quality than the permissible level when treated by a rapid sand filtration process. There was a certain trend observed that the water taken from the sources with small catchment areas, was prone to increasing level of chlorine in the contents. Special attention should be paid to controlling the water quality to keeping a standard for the drinking water.

Raw water for some of the waterworks systems, depending upon groundwater as a source, have a rather high chloride contents with a pH value beyond the allowable maximum.

3.3.3. Existing Water Supply Facilities

(1) Intake Facilities

(a) Deep Wells

In almost all of the deep wells studied, submerged pumps are used with casing diameter of 150 mm and with the highest lift of about 80 m. There are two types of water treatment methods. Chlorine is poured directly into the wells and then the water is directly pumped up to elevated tanks. The other system works by pumping the water is pumped up to elevated tanks through aeration, sedimentation and filtration systems. The chlorine is then poured into the clear water tanks. The raw water for the latter method usually contains Fe, Mn and other minerals.

(b) Intake of Surface Water

The water surface level fluctuation in the reservoirs is considerably large in the Northeastern Region, and therefore, a special type of pump is employed or additional protection measures need to be taken up for possible cavitation for long suction would be required. On the other hand, a floating type pump is generally used for the water intake from rivers. There are several joints provided on delivery pipe with a vertical interval of every two to three meters so as change the connection depending on the prevailing water level. A centrifugal pump is mainly used for the intake pump and is driven by an electric motor and/or diesel engine.

(2) Treatment Facilities

(a) Receiving Wells

There are some reported cases of overflowing due to a short retention time of about half a minute. The capacity of the well should be increased so that the retention time should be about two (2) minutes. A notched weir, placed in the receiving well, is recommended for flow rate measurement and is essential for the proper operation of the waterworks.

(b) Flocculation Basin

The horizontal baffled channel is the most commonly used and has a retention time of about 20-25 minutes. Hereinafter it is referred as Type A. The structural design itself of Type A is quite technically reasonable, but the consideration of hydraulic loss is not sufficient. Considering some allowance for the sedimentation, it is necessary to increase the total head loss from the present 100-150 mm to 250-300 mm. There is also a problem of the breaking down of the floc.

For the above-mentioned case, the standard design of a circulation type (Type B), which is adopted in some SD by the PWD, is more preferable than that of Type A.

- Floc of the raw water quality, which is scored as 4/5 for SD. Nong Thai (ESD-2), is judged to be suited or Type (B), though at present Type (A) is adopted.

- While for SD. Sankha (ESD-6) with Floc of 2/5, Type (A) is more suited, though Type (B) is adopted at present.

(c) Sedimentation Basin

The most important problem to be urgently solved falls in the fact that cleaning can not be done during the operation, since the deposited sludge can not be smoothly drained from the valve installed at the side of sedimentation tank used by the SD. Cho Ho (ESD-1), SD Non Thai (ESD-2), SD. San Kha (ESD-6), SD. Chanuman (ESD-9) and SD. Khamcha-i (ESD-10). Particularly, the water sources of SDs waterworks are apt to affect eutrophication; therefore, the sludge cleaning is a must in effective operation of the facilities. For this sake, the design shall be developed with paid sufficient consideration of the expected sludge volume during the time of high turbidity.

(d) Rapid Sand Filter

The standard design is a gravity flow type of filtration, with a rate of 120 m^3/m^2/day. Design head loss is 900 - 1,500 mm, and this type is a conventional one except for the absence of a spare filter. More careful attention should be paid to the operation and maintenance aspects. Further discussion is made in the later paragraph 3.3.4.

(e) Chemical Feeding

The chemical used depends upon the raw water quality.

(i) Alum Feeding

Under the prevailing design, the solution does not reach a satisfactory saturation point and the dosing density fluctuates to a considerable extent. For the water treatment plants located in rural areas, therefore, it seems necessary to design the facility enabling accurate control on alum dosing capacity in accordance with the quantity and quality of the raw water taken. An effective operation can be expected only when the facilities with the proper design in this respect are used.

(ii) Slaked Lime Feeding

At present, slaked lime, which is insoluble into water, is dosed without any agitating equipments in the raw water. Soda ash application is recommendable.

(iii) Chlorine Feeding

For chlorination, bleaching powder is used and the chlorine solution is dosed at clear water tank by means of natural flow. However, there is no water level control available at the solution tank, and no control on the dosing volume could be made. The solution tank shall be provided in two tanks as a unit, so that a solution can be prepared and be used one, while the other is being used for dosing. When damages to the tanks are found, more attention shall be paid to repairing them.

(3) Distribution System

(a) Distribution Reservoir

The standard design of the distribution reservoir is a covered round-shaped reservoir made of reinforced concrete with a total capacity that would allow for a volume of equivalent of four (4) hours of water, out of the maximum daily water demand. The reservoir is equipped with a float type level meter to prevent overflowing.

(b) Distribution Pump

This pump lifts the water from distribution reservoir up to the elevated tank which is connected to the distribution pipes. The capacity of the elevated tank is two hours of the maximum daily water demand with the total head of about 20 - 25 m.

As for measurement of water delivery, a water meter of a screw type should be provided at the outlet of the distribution reservoir and before the pump, but there is none or, if there are any they are out of order, for the existing works.

Most of the pumps for emergency use are not maintained in good condition and usually only one pump is operative. Proper repairing and maintenance is necessary for improvement of operation.

(c) Elevated Tank

The elevated tank has retention time of two hours of the maximum daily water demand. The water level in it is 14 to 18 m higher than the ground surface, which is technically sufficient.

(d) Distribution Piping

For piping, asbestos cement pipes (AC) or galvanized steel pipes (GS) are used when a diameter of larger than 100 mm is needed and polyvinyl chloride pipes (PVC) are used for smaller than 100 mm. There is a standard design for piping; however, it seems that the standard is not always followed. Some pipes were found exposed in a drain ditch and in many cases, the pipe connected to each consumer are exposed and not properly installed, causing unfavourable conditions in view of sanitation.

3.3.4. Operation and Maintenance

A field survey has been made on the present operation and maintenance of the 10 ESDs. The current situation of the operation and maintenance can be briefly evaluated as follows:

(1) The original purpose of the waterworks was to supply drinking water to consumers at any time without any harm to human bodies. It is regretful to say that this is not fully understood by both the suppliers and the consumers.

In other words, a field operator controls the waterworks facilities with having little clear concept about the quality of water to be supplied. It appears that the operator does not assume any responsibility for the supply and the safety of the drinking water, and there are no complaints from the consumers as well.

(2) Waterworks facilities have been constructed rather well in accordance with the standard design. As compared with the facilities, however, there remain considerable problems in the present operation and maintenance scheme.

(3) Under these circumstances, the most urgent measures to be taken are:

- Field guidance on the most practical and suitable operation and maintenance to each site; and,
- Having sufficient funds available to maintain and repair the works, if this proves necessary.

3.3.5. Water Charge and Supply Cost

(1) Water Charge

The water charge is comprised of the basic monthly rate and the meter rate. The basic monthly rate ranges from ฿1.0 to ฿7.0, and the meter rate is in proportion to the water consumption measured by the individual water meter, ranging from ฿2.5 to ฿5.0 per cu.m.

The water charge which is fixed by the Sanitary District Board shall be approved by the Minister of Ministry of Interior through the Provincial Government and the PWD, if the waterworks is a concessional one. The water charge concerning PWA' and MWWA' facilities shall be approved by the Cabinet through their Board and Minister of Ministry of Interior.

The meter rate per cu.m, which have been applied by PWA, are shown as follows;

Monthly Usage (cu.m/m)	Rate (฿/cu.m)
0 - 10	3.75
11 - 20	4.50
21 - 50	5.50
51 - 80	6.50
81 - 100	7.00
101 - 300	7.50
301 -	8.00

The annual water charge per household is estimated to correspond to one to four percent of the annual average income per household.

(2) Water Supply Cost

The water supply unit cost was analyzed in order to clearly understand the financial situation. From the results of the analysis, the water supply unit cost per cubic meter is between ฿2.1 to ฿5.9 with ฿3.4 on an average.

The unit cost is composed of seven kinds of expenses and the breakdown of the unit cost on the average is as follows;

	$฿/m^3$	Percent
Personnel expense	0.7	19.5
Office expense	0.5	15.4
Energy expense	0.9	27.4
Chemical expense	0.4	11.1
Repair expense	0.4	11.1
Loan repayment	0.4	11.0
Others	0.1	4.5
Total	3.4	100.0

Water supply cost and the water charge of the respective ESDs are shown in Figure F-2-1 in Appendix F.

3.3.6. Financial Support of the Project

The ESD waterworks are generally operated and maintained on the self-supporting system. The water charge collected is the only source of revenue for operation and maintenance as well as repayment of the long-term loan from Sanitary District Promotion Fund. This Sanitary District Promotion Fund is under the Central Government, and is sometimes used for the expansion of projects, the replacement of facilities and the repair of some minor works. The loan conditions are listed as follows:

- the amount of the loan: 10 times as much as SD's savings
- the repayment time : 15 years
- the interest rate : 4 percent per year

CHAPTER IV.   SELECTION OF SANITARY DISTRICT TO BE STUDIED

CHAPTER IV. SELECTION OF SANITARY DISTRICTS TO BE STUDIED

4.1. Selection Criteria

4.1.1. General Description

The implementation of waterworks projects requires a huge amount of investment, which affects significantly the inhabitants, society, and economy of the project areas. A detailed study at the stage of plan formulation should be carried out in order to execute waterworks project properly and smoothly, along with a priority in project implementation, feasibility, and economic soundness.

4.1.2. Items of Selections Criteria

The selection criteria, in setting priorities for the project implementation, should take into consideration human needs for drinking water, social conditions of the subject areas, capability of repayment of investment, appropriation of initial and operation and maintenance costs as major elements.

(1) Human Needs and Social Conditions

Domestic water is physiologically indispensable for human life. There are many difficulties and constraints in securing drinking water in rural areas. It is obvious that stable water sources with good quality are required as well as social environmental development.

The criteria for human needs are based on the total population, population growth rate, population density and occurrence rate of diseases by drinking water. The occurrence ratio of water-borne and water related diseases to the population in the subject areas is about 0.6 to 1.0 percent on an annual average.

(2) Capability of Payment and Construction Cost

(a) Capability of Payment

A water supply is essential for mankind to secure a healthy and safe lifestyle, but basic economic base and further economic resources of the people are indispensable for long-lasting operation and maintenance after project completion, in addition to the burden of the initial construction costs to the beneficiaries. The capability of payment, therefore, is based on the average income per person and major industry, such as agriculture in the case of Northeastern Thailand, and the location of the main road for marketing activity.

(b) Construction Cost

The construction cost of a water supply system in the NSD is decided as a result of detailed studies on several alternative plans considering various technical and economical standpoints. The unit water cost and water cost per beneficiary indicate effectiveness of investment cost.

4.1.3. Selection Method

(1) Weighing of Evaluation Items

The following items in the comprehensive evaluation of each NSD were proposed, appropriately weighing each category.

Item	Weight
1. Human Needs	50
- Total population	20
- Population growth rate	15
- Population density	10
- Occurrence ratio of diseases caused by drinking water	5
2. Payment Capability and Construction Costs	50
a. Payment capability	25
- Average income per beneficiary	10
- Agricultural land acreage per person around SD	10
- Distance between SD and main road (for marketing conditions)	5
b. Construction cost	25
- Unit water cost	15
- Water cost per beneficiary	10

(2) Conception of Weighing Item

Population: Total population, growth rate and density components of each NSD play a vitally important role in the necessity of the Project implementation. The data analysis is made on the population census for the last ten years.

Water-borne diseases: The rate of disease occurrence by drinking water and others related thereto is evaluated on the number of diseases contracted to the total population in the NSD concerned.

Income capability: According to the 1970/80 Socio-Economic Survey by the NSO, the SD's have about 50 percent of the population dependent upon agricultural population, and the economic/social activities and growth in the SD would be subject to agriculture. The average monthly income per household in the SD in the northeastern region is about ฿1,349 per agricultural household and ฿2,633 per non-agricultural household, respectively.

Farmland scale: In connection with the above mentioned income, the individual holding acreage of agricultural land within a 5.0 km radius from the center of the SD is computed for the purpose of measuring the economic scale of the SD.

Marketing condition: The distance between SD and a major road (national and provincial road) is evaluated to compare the social and economic conditions of the SD, which are being in a position to be core of socio-economic activity in the surrounding agricultural area.

Unit construction cost: The construction cost to be allocated to the water per cubic meter per hour and per capita served is very important indicator for the project evaluation. The total construction cost, therefore, shall be studied with careful considerations on a minimum cost basis. Many possible alternatives studies for the respective SD shall be made on the preliminary level.

4.2. Selection of Sanitary District

4.2.1. Preliminary Design of System and Cost Estimate

(1) Basic Planning and Preliminary Design of System

The fourteen (14) new Sanitary Districts (NSD) to be studied in the pre-feasibility study phase were chosen by the Government of Thailand.

Basic projection for water demand and the population served, available water resources, NSD boundary and socio-economic conditions were determined using the manner and concept which is described in Chapter V, along with the findings of the field investigations.

A preliminary system design for the respective NSD's was also made in accordance with the design criteria, including typical structure drawings and the alternative study results of the proposed water resources. The selection and evaluation of the available water resources were made with particular attention to the storage capacity of the reservoirs in the dry season and the water quality of existing deep wells in and around the NSD. The comparative study of the alternatives was made only for comparison of stored water usage in the existing reservoir and groundwater.

The preliminary cost estimate of the system required for each NSD was made on the basis of initial investment cost excluding the operation and maintenance cost, which is negligible compared to the initial investment cost.

4.2.2. Comprehensive Evaluation of NSD

The general features of the fourteen NSD are described as follows;

NSD Code No.	NSD Name	Changwat	Population in 1984
2	Rong Kham	Kalasin	4,886
5	Kham Sakae Sang	Nakhon Ratchasima	4,816
6	Non Bua Lai	Nakhon Ratchasima	3,314
7	Huai Thalaeng	Nakhon Ratchasima	9,598
8	Nong Ki	Buri Rum	13,100
9	Hin Lek Tai	Buri Rum	5,086
10	Huai Rat	Buri Rum	3,785
11	Sai Mun	Yasothom	6,087
12	Khun Han	Si Sa Ket	3,137
13	Kusuman	Sakhon Nakhon	5,248
15	Dong Khuang	Sakhon Nakhon	13,460
17	Phon Charoen	Nong Khai	9,697
18	Nong Song Hong	Nong Khai	7,914
20	Huai Kha Yung	Ubon Ratchathani	3,813

The comprehensive evaluation and recommendations of NSD were carried out in accordance with the selection criteria set forth, basic planning, preliminary design and cost estimate. The results of the evaluation are summarized in Table 4-2-1 and the details are tabulated in Appendix C.

Based on the results of the study, as shown in Table 4-2-1, a discussion meeting was held between the Thai authorities concerned and the JICA team to select ten(10) NSDs according to the priorities established, but excluding the NSD named Dong Khung. Dong Khung Sanitary District was excluded from the proposed NSD to be studied in spite of its high priority (priority No.3), because the project area has already been incorporated into the implementation scheme of Provincial Waterworks Authority. So four NSDs, namely Rong Kham, Hin Lek Fai, Sak Mun and Dong Khung were eliminated from the feasibility study.

Table 4-2-1. Evaluation Score of NSD

NSD Code No.	Name of NSD	Human Needs	Payment Capability	Construction Cost	Total Score	Priority
(Maximum Score)		(50)	(25)	(25)	(100)	
2	Rong Kham	21.6	19.6	13.0	54.2	12
5	Kham Sakae Sang	26.3	16.0	12.6	54.9	11
6	Nong Bua Lai	20.6	22.0	14.7	57.3	8
7	Huai Thalaeng	35.6	9.5	11.2	56.3	9
8	Nong Ki	42.8	14.2	17.9	74.9	1
9	Hin Lek Fai	21.8	11.5	11.3	44.6	14
10	Huai Rat	23.7	20.9	17.9	62.5	7
11	Sak Mun	23.9	15.1	13.7	52.7	13
12	Khun Han	22.8	22.0	23.0	67.8	2
13	Kusuman	29.2	16.0	20.8	66.0	5
15	Dong Hung	35.6	14.8	16.5	66.9	3
17	Phon Charoen	27.5	14.1	14.1	55.7	10
18	Nong Song Hong	26.0	15.8	25.0	66.8	4
20	Huai Kha Yung	27.8	23.0	14.4	65.2	6

CHAPTER V.   WATER DEMAND AND WATER SOURCE

CHAPTER V. WATER DEMAND AND WATER SOURCES

5.1. Population Projection

5.1.1. Service Area

The service area of the water supply covers generally whole Sanitary District area, which is defined in the Sanitary District Act.

The people who are living within the SD areas shall be ready to enjoy the benefit from the waterworks at the low rate of cost, although will have to pay the cost of laying the pipe from the mains to individual houses. Therefore, the main pipes have to be installed to supply the water to every household in the service areas from the initial stage of the operation of waterworks. The actual service connection will be made by the beneficiary.

5.1.2. Service Level

The service level in the proposed waterworks is divided into three categories; (1) a house connection made to the individual households, (2) a yard connection that would serve several households, and (3) a public stand tap serving about twenty households. Needless to say, the most desirable service level is that of the house connection, from the viewpoint of convenience and sanitary conditions, but the service level such as the yard connection and the public stand tap, should be considered to utilize the limited capital and to serve as many people as possible. When the yard connections or the public stand taps are widely provided in the peripheral areas where many farmers live, convenience of the people will be improved. As a basic target of the Project, however, the house connection system was considered in most NSD areas.

5.1.3. Target Year

The target year of the Project is the year 2000, taking into account the social development tendency of the Sanitary District areas and the investment effect of the Project.

5.1.4. Population Served

There are many different methods to calculate the population projection at the specified target year.

Population increase in the subject area will depend upon the development policy of the area, investment scale to the infrastructure, socio-economic conditions and so forth. The population projection in the Sanitary Districts, therefore, is made by the method of the annual average increasing factor. The majority of the proposed Sanitary District areas consist of non-agricultural areas and agricultural areas. The forecast of the population was made by adding the annual population growth rate of the non-agricultural and the agricultural area.

The average growth rates of population per year of the NSDs were calculated on the basis of the data collected for the latest available population census. The results of calculation on the average growth rate per year are 5.8 percent for the non-agriculture area, 2.3 percent for the agriculture area which result a 2.8 percent of the total, as tabulated in Table A-1-1 of Appendix A.

The future population, therefore, was estimated by the following formula;

$$yt = ya + yn$$
$$ya = yoa\ (1 + 0.023)^{x}$$
$$yn = yon\ (1 + 0.058)^{x}$$

Where, yt = future total population
ya = future agricultural population
yoa = agricultural population in 1984
yn = future non-agricultural population
yon = non-agricultural population in 1984
x = years counted from the base year, 1984

With SD Dong Khuang (NSD-15), SD Phon Charoen (NSD-17), and SD Nong Song Hong (NSD-18), the following formula was used because there is no data on the agricultural area growth vs. the non-agricultural area growth in these SD.

$$yt = yo\ (1 + 0.028)^{x}$$

Where, yt = future total population
yo = total population in 1984
x = year counted from base year, 1984

The results of population projection in respect to the target year are summarized in the following table and the detailed tabulation is shown in Table A-1-2 of Appendix A.

Population Projection

(Unit: persons)

NSD Code No.	NSD Name	1984	1990	1995	2000
5	Kham Sakae Sang	4,816	5,926	7,098	8,559
6	Nong Bua Lai	3,314	4,197	5,151	6,366
7	Huai Thalaeng	9,598	12,304	15,251	19,028
8	Nong Ki	13,100	16,324	19,761	24,089
10	Huai Rat	3,785	4,735	5,752	7,037
12	Khun Han	3,139	4,266	5,529	7,190
13	Kusuman	5,428	6,323	7,433	8,788
17	Phon Charoen	9,697	11,444	13,139	15,084
18	Nong Song Hong	7,914	9,340	10,723	12,310
20	Huai Kha Yung	3,813	4,751	5,751	7,011

According to the information on the concessional waterworks of the ESD, shown in Table A-1-3 of Appendix A, the rate of service on an average is more than 60 percent. In due consideration of the rate of service of the ESD waterworks, the rate of service for the NSD was estimated to be 50 percent in 1990, 60 percent in 1995, and 70 percent in 2000, with some allowance.

5.2. Water Demand

5.2.1. Definition of Water Demand

Water demand is defined as water consumption of various users such as domestic, public, commercial, industrial and the leakage/ wastage of water supply system.

5.2.2. Water Consumption and Water Demand

(1) Water Consumption

Water consumption was determined based on the water consumed at existing waterworks and the records provided by the PWD due to lack of data and information on the water consumption of the respective users. The daily water consumption per capita in the ESDs was evaluated at about 65 lcd for a rather small scale and at about 90 lcd for medium scale waterworks, respectively as shown in Table A-2-1 of Appendix A.

According to the survey results of the water leakage and wastage at existing waterworks, the average rate of leakage/wastage to the total water demand is about 49 percent as shown in Table A-2-2.

On the other hand, the average daily water demand of the medium scale waterworks in Thailand is about 179 lcd as shown in Table 3-3-1. From the above-mentioned concept, the average water consumption can be assessed to be about 90 lcd. This value would be considered to suggest the future status of the new Sanitary District waterworks in the target year of 2000.

The target value of the leakage and wastage rate is expected to decrease by about 0.25 gradually, from present supply level, taking into consideration improved techniques of operation/maintenance, and a patrol system of the waterworks into consideration.

(2) Water Demand

As described in the item 3.3.1, that the average daily water demand in 2000 is 120 lcd. Based on the average daily water demand, the following design index can be defined.

(a) Maximum Daily Water Demand

The rate of the maximum daily water demand is equal to the average daily water demand in NSDs multiplied 1.25.

According to the data collected from ESDs, reference materials, and measured records in the Chonnabot ESD of Changwat Khon Kaen, the values are found variable from 1.2 to 1.5. The ratio will fluctuate by seasonal climate conditions, the standard of living and the scale of the urbanized service area.

The records at Chonnabot clearly show a variation throughout the year, as illustrated in Figure A-2-1 in Appendix A.

(b) Maximum Hourly Water Demand

The rate of maximum hourly water demand to the average hourly water demand at the time of maximum daily water demand varies with the difference of population between the daytime and the night in the service area, the water consumption type of the factories and offices, the seasonal fluctuation in the number of visitors at the tourism areas, etc. In general, the rate ranges from 1.2 to 2.5 depending upon the conditions of the service area.

According to the survey by JICA Study Team on the actually released water by Chonnabot Water Supply System, the hourly released water amount and the ratio to the average hourly discharge are shown in Table A-2-3 of Appendix A.

It can be determined that the rate of maximum hourly water demand is about 1.97 from Table A-2-3. It is converted that the rate of maximum hourly water demand to average hourly water demand at the time of maximum daily water demand is about 1.58.

On the other hand, the rate stipulated in the PWA's design criteria is just 1.50. Therefore, the rate is to be 1.50 in taking into consideration the reason mentioned above and in saving the investment cost for the distribution system.

5.3. Water Sources

5.3.1. General

Potential water sources of the subject Sanitary District waterworks are considered to have several alternatives, such as rivers, ponds, reservoirs, and groundwater. As mentioned in the previous chapter, the water sources for the subject project should be stable quantitatively and qualitatively throughout the year. Potential water sources of the proposed SDs have been surveyed sufficiently during the course of field survey by the Team with close cooperation of the PWD and respective NSD officials concerned. As the results, it can be confirmed that the stored water in the reservoir is a major stable water source for the subject project. Surface water from the river, with comparatively small catchment areas, is not a stable source, as it will run dry in the dry season.

The stored water sources are reservoirs, natural ponds, and lakes. The majority of the proposed reservoirs have been constructed by the Royal Irrigation Department for the purpose of irrigation and domestic water supply.

On the other hand, the survey of groundwater as the sources was carried out carefully by the PWD and the Team after existing data and information from Department of Mineral Resources had been studied and evaluated. The actual investigation was made only for five NSD areas out of proposed ten areas.

5.3.2. Rivers

The Northeastern Region belongs to the watershed of the Mae Khong river, and the rivers in this region are almost all tributaries of the Mae Khong. The main tributaries are the Mun, the Chi and the Song Khram.

The fluctuation of discharge between the dry and the rainy seasons is extremely large, and the rivers with small catchment areas are usually dried up in the dry season. According to the information of RID, the drought discharge at 10-year-return period in this region ranges from 0.01 to 0.04 cu.m/s/100 sq.km. Consequently, a catchment area of such rivers would need more than 1,000 sq.km to meet the proposed water demand in each NSD for direct intake. After a detailed study, the Huai Kha Yung SD was proposed to use the river water source for the water works project.

5.3.3. Reservoirs

The reservoirs, with a large capacity, are reliable as water sources of the NSDs in terms of both quantity and quality. According to the results of the survey and the evaluation of the hydrological data available for the existing reservoirs, it is found that capacities of the reservoirs have gradually decreased by sedimentation of silt. Evaporation and shallowness of the reservoirs are serious problems as well.

In the case of utilizing the existing reservoirs as water sources, a special attention should be paid to not giving priority to any of purposes such as domestic use, irrigation use, and others.

According to the information collected from government agencies concerned, there are three types of existing ponds or reservoirs. One type is used mainly for a domestic water supply with irrigation only done with excess water, one type is for irrigation only, and one type are natural ponds. The reservoirs which were constructed under the small scale irrigation programme (SSIP) and the accelerated rural development project by Ministry of Interior have given the first priority to domestic water supply. Any excess water can be used for irrigation or other purposes. On the other hand, water of the reservoirs which were constructed by Royal Irrigation Department, are to be used for irrigation as the first priority. Also the stored water of the reservoirs, which were constructed by the Medium Scale Irrigation Projects (MSIP), the King's Projects and the Tank Irrigation Projects under the Royal Irrigation Department are to give for irrigation the first priority. If the reservoirs have excess storage capacity, even in ten year return period of drought, the excess water can be used for other purposes such as Sanitary District water supply works.

Operation and maintenance of these reservoirs under the SSIP are made by the Changwat after the facilities are taken over from RID. According to the regulation on the said reservoir operation, if the inhabitants living near the reservoirs can accept to use the stored water for a domestic water supply, rather than irrigation and other uses, then the first priority of water use can be given to the domestic water supply.

The study and review on the availability of the existing water resources were made based on the above mentioned criteria. Considerable potential water sources are listed in Table 5-3-1.

5.3.4. Groundwater

The existing irrigated areas and densely populated areas extend mostly in the Khorat Aquifer within the main artery of the plateau. Groundwater of this aquifer is variable in both quantity and quality. The average depth of the water level in the aquifer ranges from six to 10 m and the drawdown at the pumping rate is approximately 30 m. Wells drilled to the depth of about 30 to 120 m yield one to 10 cu.m/hr. In relatively flat land, efflorescent salt often occurs on the ground surface, and more than 90 percent of drilled wells yield salty water. The possibility of ground water at each NSD has been studied by reviewing the hydrogeological data prepared by PWD, DMR, ARD, RID and DH. Consequently, five of SDs, No.5, No.7, No.13, No.17 and No.18 have been selected and a geoelectric prospecting survey and a well drilling works with a pumping test were conducted by the PWD and Study Team.

The results of pumping test for five drilled wells are discussed in Appendix A and the following are the summary of the analysis.

NSD Code No.	Name of NSD	Pumping Rate (cu.m/hr)	Draw Down (m)	Chloride (ppm)
5	Kham Sakae Sang	2.5	20.8	280
7	Huai Thalaeng	1.7	15.1	270
13	Kusuman	18.4	6.6	70
17	Phon Charoen	10.0	18.2	8
18	Nong Song Hong	10.8	11.9	6

The following conclusion on the groundwater development was reached through careful evaluation.

- Two drilled wells for Kham Sakae Song and Huai Thalaeng are not acceptable as stable drinking water sources from the view point of water quantity and quality.

- Drawdown depth by pumping rate in Kusuman area seems rather small. It is considered that the capacity of the pump used in pumping test was rather small as compared with its pumping rate.

  Safety yield of 18 cu.m/hr was estimated based on the "Time-Residual Draw Curve".

- Safety yield for both wells of Phon Charoen and Nong Song Hong was evaluated to be about 7.0 and 7.5 cu.m/hr, respectively. It is for this reason that the safety yield of ground-water from these deep wells was determined to be reduced about 60 to 70 percent out of the total pumping rate.

Table 5-3-1 Lists of Potential Water Source

SD No.	Water Source	Managing Agency	Major Used	Project Name	Storage Capacity (MCM)	Annual Inflow (MCM)	Catchment Area (sq.km)	Remarks
5	Bun Chiwuk Res.	C	D.W	SSIP	0.336	0.207	1.0	Existing
6	Non Sanp Res.	-	D.W	-	0.300	-	-	"
6	Phai Luang Res.	C	I	SSIP	0.368	2.484	12.0	"
7	Lam Chamuak Res.	RID	I	MSIP	22.200	43.764	180.0	"
7	Nong Takai Res.	C	I	SSIP	0.155	1.863	9.0	"
8	Tung Kraten Res.	C	D.W	ARDP	1.600	7.244	35.0	"
10	Huai Talet Res.	RID	I	MSIP	18.500	71.506	153.0	"
12	Nong Si Res.	RID	I	MSIP	3.800	18.758	32.4	"
13	Huai Daeng Res.	RID	I	King'sP	1.150	5.780	10.5	"
17	Nong Loeng Res.	C	I	SSIP	2.000	4.700	8.4	"
18	Nong Song Hong Res.	RID	I	TankP	0.380	2.126	3.8	"
18	Nong Kom Ko Pond	-	D.W	-	10.000 *1	16.770 *2	30.0	"
20	Huai Kha Yung (River)	-	-	-	-	11.7 *3 cu.m/sec	3344.0	"
5	New Reservoir (270 x 270 x 3m)	-	D.W	-	0.219	-	14.0	Planning
13	New Reservoir (270 x 270 x 3m)	-	D.W	-	0.219	-	20.0	"
17	New Reservoir (370 x 370 x 3m)	-	D.W	-	0.411	-	24.0	"
13	Ground Water	PWD	D.W	-	-	18.0 *4 cu.m/hr	-	Deep Well
17	"	PWD	D.W	-	-	7.0 *4 cu.m/hr	-	"
18	"	PWD	D.W	-	-	7.5 *4 cu.m/hr		"

Note: PWD ; Public Works Department
C ; Changwat
RID ; Royal Irrigation Department
I ; Irrigation
D.W ; Domestic Water
SSIP; Small Scale Irrigation Project
MSIP; Medium Scale Irrigation Project
ARDP; Accelerated Rural Development Project

*1; Surface area (4 sq.km) x Effective Depth (2.5m)
*2; Average runoff (559mm) x 30 sq.km
*3; Drought discharge at 10 year return period at intake point.
*4; Result of pumping test

5.4. Water Quality Evaluation

5.4.1. Sampling and Analysis

Water sampling and testing of the water sources to be developed for ten NSDs were carried out during the field survey. The collected raw water samples were analyzed at both field sites and laboratories. The results of analysis are shown in Table 5-4-1 and 5-4-2 for both the surface water and the ground-water, respectively.

5.4.2. Evaluation and Suitability

Major findings and consideration of raw water quality for NSDs are discussed as follows;

(1) Surface Water

pH values	:	The value ranges from 6.4 to 7.5 and there are found no problems as drinking water.
Turbidity and colour	:	Maximum permissible level of colour unit in Thai standard is 15. The unit of the tested raw water is rather high due to dense contents of iron (Fe). Some samples showed slightly high turbidity as compared with Thai standard. The problems, however, could be solved by providing appropriate water treatment system.
Cl (ppm)	:	Maximum permissible level of the standard is 600. NSD No. 5, Kham Sakae Song value was about 900. Samples of water was taken from the bottom of reservoir in complete drawdown.

(2) Groundwater

Major difficulties in water quality of the existing deep wells in and around New Sanitary Districts are mainly the high density of chloride and iron content, and the turbidity problem which is possibly affected by the iron content.

The extremely large values of chloride density are observed at the NSDs No.5, No.7 and No.8 and of iron content and color unit in No.7, No.17 and No.18.

The well drilling and pump testing for the NSDs No. 5, 7, 13, 17 and 18 were carried out based on the result of electric prospecting measurement made by the staff of PWD's Well Drilling Division staff and study team in order to confirm water quantity and quality.

As shown in Table 5-4-2, water quality of the NSDs No.5 and No.7 are not suitable for drinking due to high contents of iron, chloride and total hardness, and moreover, quantity of water as safety yield is extremely small in amount. The remaining three drilled wells can be used as drinking water sources without much investment for water treatment.

The final conclusion on utilization of the groundwater resources will be discussed from the viewpoint of not only quantitative and qualitative aspects of groundwater but also such economic aspect of the proposed systems, capital investment cost and operation/maintenance cost at a later stage.

Table 5-4-1 Water Quality of Proposed Surface Water Resources

(17 June to 11 July 1985
11 November to 16 December 1984)

No.	NSD	Water Source	PH	Turb. (NTU)	Color (unit)	$KMnO_4$ Consumption (mg/ℓ)	Fe (mg/ℓ)	Cl (mg/ℓ)	Alkalify (mg/ℓ)	Jar Test: Floc Form	Jar Test: Alum Feeding (mg/ℓ)	Jar Test: Alkalify Feeding
5	Kham Sakae Sang	Bunchiwuk Reservoir	6.7	50	25	30.5	0.1	900	86	4/5	20-30	-
6	Nong Bua Lai	Nong Sanp Reservoir	7.5	55	15	28.5	9.0	19	73	4/5	20-30	-
7	Huai Thalaeng	Nong Takai Reservoir	7.4	12	15	20.8	1.2	19	146	2/5	10-20	-
8	Nong Ki	Toong Katen Reservoir	7.5	200	30	30.8	2.25	41	82	4/5	40	-
10	Huai Rat	Ram Huai Rat River	7.3	220	20	28.5	10	13	63	4/5	40	-
12	Khun Han	Nong Si Reservoir	6.4	8	-	-	0.4	4	-	2/5	10	10
13	Kusuman	Huai Daeng Reservoir	7.5	30	20	7.4	1.15	5	17	2/5	20	10
17	Phon Charoen	Nong Loeng Reservoir	6.8	25	30	2.28	0.45	8	10	2/5	20	20
18	Nong Song Hong	Nong Song Hong Reservoir	7.2	9	15	13.7	0.85	8	20	2/5	10	10
20	Huai Kha Yung	Huai Kha Yung River	7.4	40	15	21.5	2.85	10	24	2/5	30	15

Table 5-4-2 Ground Water Quality of Drilled Well

Item	[5] Kham Sakae Sang	[7] Huai Talaeng	[13] Kusuman	[17] Phon Charoen	[18] Nong Song Hong
Date	10/Sep., 1985	10/Sep., 1985	6/Oct., 1985	3/Oct., 1985	14/Sep., 1985
1. PH	7.8	7.8	7.9	8.2	8.0
2. Turb. NTU.	66	42	11	12	12
3. Color unit	6	4	5	7	2
4. Total Hardness $CaCO_3$	824	1,340	354	190	240
5. Ca (mg/ℓ)	141	401	93	62	74
6. Mg (mg/ℓ)	115	83	30	8	13
7. Fe (mg/ℓ)	2.3	2.2	0.71	0.55	0.88
8. Mn (mg/ℓ)	0.04	0.52	0.10	0.15	0.02
9. Cl (mg/ℓ)	280	270	70	8	6
10. Nitrate (mg/ℓ)	0.67	4.3	1.6	0.1	0.2
11. Nitrite (mg/ℓ)	0.01	0.16	nil	nil	nil
12. COND	105	2,900	700	375	425

Remarks:
Date ; Analysising date,
Turb ; Turbidity,
Ca ; Calcium,
Mg ; Magnesium,
Fe ; Iron,
Mn ; Manganese
Cl ; Chloride,
Nitrate ; Nitrite, expreased as nitrogen,
Nitrete ; Nitrite, expreased as nitrogen,
COND ; Electrical conductivity at 25°C(micromhos/cm)

Note : Underlined figure indicates comparatively high value.

5.5. Water Balance Study and Availability of Water Sources

5.5.1. Hydrological Consideration

(1) General

Hydrological review of the subject water sources was concentrated on the surface water runoff analysis since the majority of water sources are stored water in the existing reservoirs. As discussed in the previous paragraph, available groundwater for subject Sanitary Districts from the viewpoint of quantity and quality, could be found in a limited area only.

(2) River Runoff

The river runoff from the relevant catchment area is affected by many factors such as topographic conditions and vegetation, and rainfall intensity. Most of the proposed water resources have no detailed runoff records and hydrological information. The runoff analysis for the project, therefore, was carried out based on the rainfall records of the subject area and the runoff estimation chart prepared by RID. Specifically, the runoff coefficient calculated for Northeast Thailand is quite small due to a large amount of losses in the initial stage of rainfall accumulation, but the runoff will increase gradually along with accumulated rainfall.

(3) Water Losses from Reservoirs

The major water losses from the subject reservoirs were estimated on a monthly basis, taking into consideration evaporation from water surface of the reservoirs. Evaporation losses can be estimated by calculating 70 percent values of year-round observation values by Class A-Pan.

(4) Design Drought Year

The design drought year for the project is to take place once in ten years taking into consideration importance of human needs, effective investment to the project facilities and stable water supply.

(5) Water Demand of Waterwork

The diversion water requirement at the reservoir was determined at 110 percent of the average design discharge at the distribution reservoir in the water treatment plant.

(6) Irrigation Water Requirement

Typical irrigation water requirement can be computed by RID standard method and cropping pattern/cropping acreage in the service area concerned. The figures applied to water requirement computation are summarized as follows:

		Rainy Season	Dry Season
- Cropping Calendar			
Nursery bed, land soaking	:	15 Jun. to 31 Jul.	15 Dec. to 31 Jan.
and preparation	:	1 Aug. to 30 Oct.	1 Feb. to 30 Apr.
- Water Requirement at Field			
Land soaking and preparation	:	200 mm	230 mm
Evaporation and percolation during land preparation	:	200 mm	230 mm
Field irrigation	:	810 mm	1,036 mm
Total		1,210 mm	1,496 mm

During rainy cropping seasons, there is a considerable amount of rainfall which is useful as irrigation water. Actual supplemental irrigation water requirement can be computed by the following formula.

$$S.W.R. = \frac{\text{Field W.R - Effective Rainfall}}{\text{Irrigation Efficiency (0.65)}}$$

(7) Water Balance Simulation Concept

The water balance computation of the reservoir is expressed by the following equation.

$$V = I - W - IR - L$$

V : Storage volume of the reservoir
I : Inflow into reservoir
W : Water demand for the water supply
IR: Irrigation water requirement (if any)
L : Water losses from reservoir

In case of utilizing the existing reservoirs as water sources, there are two types of reservoirs such as used mainly for domestic water supply with irrigation done only using excess water and used mainly for irrigation as given the first priority. The flow chart of water balance simulation is shown in Figure 5-5-1.

5.5.2. Water Balance Simulation and Evaluation

(1) General

Water balance simulations were conducted by using the available data mentioned previously, and the detailed description and simulated output were discussed and tabulated in Appendix A. The results of the simulations and the evaluations for the respective NSD water sources are presented in this chapter.

(2) Kham Sakae Sang (NSD, No.5)

- The Bun Chiwuk reservoir, which was constructed by RID in 1980, is located at 5.0 km west of the SD area. The effective storage capacity is about 336,000 cu.m, but there was no stored water confirmed during the second phase of the field survey due to less rainfall and its relatively small catchment area in comparison with the storage capacity. For a stable water supply to NSD, a diversion dam from Huai Yang was proposed as a transbasin water resources.
- Huai Ruam, with a catchment area of about 14 sq.km, is flowing near the SD. The construction of a new reservoir would supply water to the NSD throughout the year.

- Conclusion: It is confirmed that if a diversion canal from Huai Yang to Bun Chiwuk reservoir with 2.0 cu.m/sec capacity can be provided, there is no water deficit even in the critical drought period in the dry season.

(3) Nong Bua Lai (NSD, No.6)

- The Nong Sanp pond with the storage capacity of 300,000 cu.m is located in the SD. Phai Luang reservoir, which was constructed by RID in 1980, is located at 2.0 km upstream of the said pond. The storage capacity is 368,000 cu.m. It is possible to divert water from the Phai Luang reservoir to the Nong Sanp pond effectively.

- Conclusion: There is no deficit in the amount of storage water, and the water will be able to be supplied sufficiently.

(4) Huai Thalaeng (NSD, No.7)

- The Lam Chamuak reservoir with storage capacity of 23.5 MCM which was constructed for irrigation by RID is located 20 km northwest of SD.

- The Nong Takai reservoir which was constructed by RID in 1980 is located 5.0 km north of the SD. The storage capacity is 155,000 cu.m. The heightening of the dam embankment will be required to meet the proposed water demand.

- Conclusion: In the case of using Lam Chamuak reservoir, a water deficit will be three times as likely to occur within the 22 years simulation period with the year-round irrigation, if no countermeasures are taken for existing reservoir improvement. In the case of using Nong Takai reservoir, heightening of the embankment by 1.5 m will be required for stable water supply.

(5) Nong Ki (NSD, No.8)

- The Tung Kraten reservoir with storage capacity of 1.6 MCM, which was constructed by ARD in 1969, is located 2.0 km north of the SD.

- Conclusion: There are no remarkable problems even in a critical drought period.

(6) Huai Rat (NSD, No.10)

- The Huai Talet is flowing one km west of the SD. Huai Talet reservoir, which was constructed by RID, is located in the Huai Talet. The storage capacity is 19.2 MCM. This reservoir water is conveyed to an irrigation area through the left and the right main canals, which will be expected to be improved with a concrete lining. Therefore, raw water of the subject project could be diverted at the terminal point of right main canal.

- Conclusion: There has occurred water shortages two times during for 19 years, when irrigation and domestic water supply were made throughout the year. It is acceptable as stable water supply.

(7) Khun Han (NSD, No.12)

- The Nong Si reservoir with storage capacity of 3.8 MCM, which was constructed by RID, is located near the proposed Sanitary District.

- Conclusion: As the results of water balance simulation for both cases, one of the original proposed SD area and that with the expansion area added, there is no water shortage even in full scale irrigation practiced for the benefit of farm land.

(8) Kusuman (NSD, No.13)

- The Huai Daeng reservoir, which was constructed by RID, is located 5.0 km east of the SD. The storage capacity is 1.15 MCM.

- The Huai Saphoe with catchment area of 20 sq.km is flowing near the SD. The construction of a new reservoir will be considered.

- As safety yield of about 18 cu.m/hr from newly drilled well is available for water supply works.

- Conclusion: In case of using the reservoirs, there is no deficit even when irrigation will be practised continuously.

(9) Phon Charoeng (NSD, No.17)

- The Non Loeng reservoir, which was constructed by RID, is located 12.5 km west of the SD. The storage capacity is 2.0 MCM.

- The Huai Som Hong with a catchment area of about 24 sq.km is flowing near the SD. The construction of a new reservoir will be considered.

- Judging from the result of the pumping test, the safe yield of the drilled well is 7.0 cu.m/hr and four wells will possibly be drilled in and around the SD area.

- <u>Conclusion</u>: In case no improvement of the existing dam is made, 50 ha of irrigation area would have to be reduced out of 300 ha of the present area, when domestic water is fully supplied. By using groundwater as a supplemental water sources, there is no water shortage, without any reduction of irrigation area, even in a critical drought period.

(10) Nong Song Hong (NSD, No.18)

- The Nong Song Hong reservoir, which was constructed by RID, is located 2.0 km south of the SD. The storage capacity is 380,000 cu.m. The heightening of the dam embankment will be required to meet the proposed water demand.

- The Nong Kom Ko pond is located 10 km north of the SD. The storage capacity is approximately 10.0 MCM.

- Judging from the result of pumping test, safe yield of the drilled well is 7.5 cu.m/hr and three wells will be able to be constructed in and around the SD area.

- <u>Conclusion</u>: Heightening of dam embankment by 1.30 m will be required when water in the Nong Song Hong reservoir is used for both irrigation and domestic water supply. In case of using groundwater as supplemental water sources, 1.10 m heightening of the embankment will still be needed.

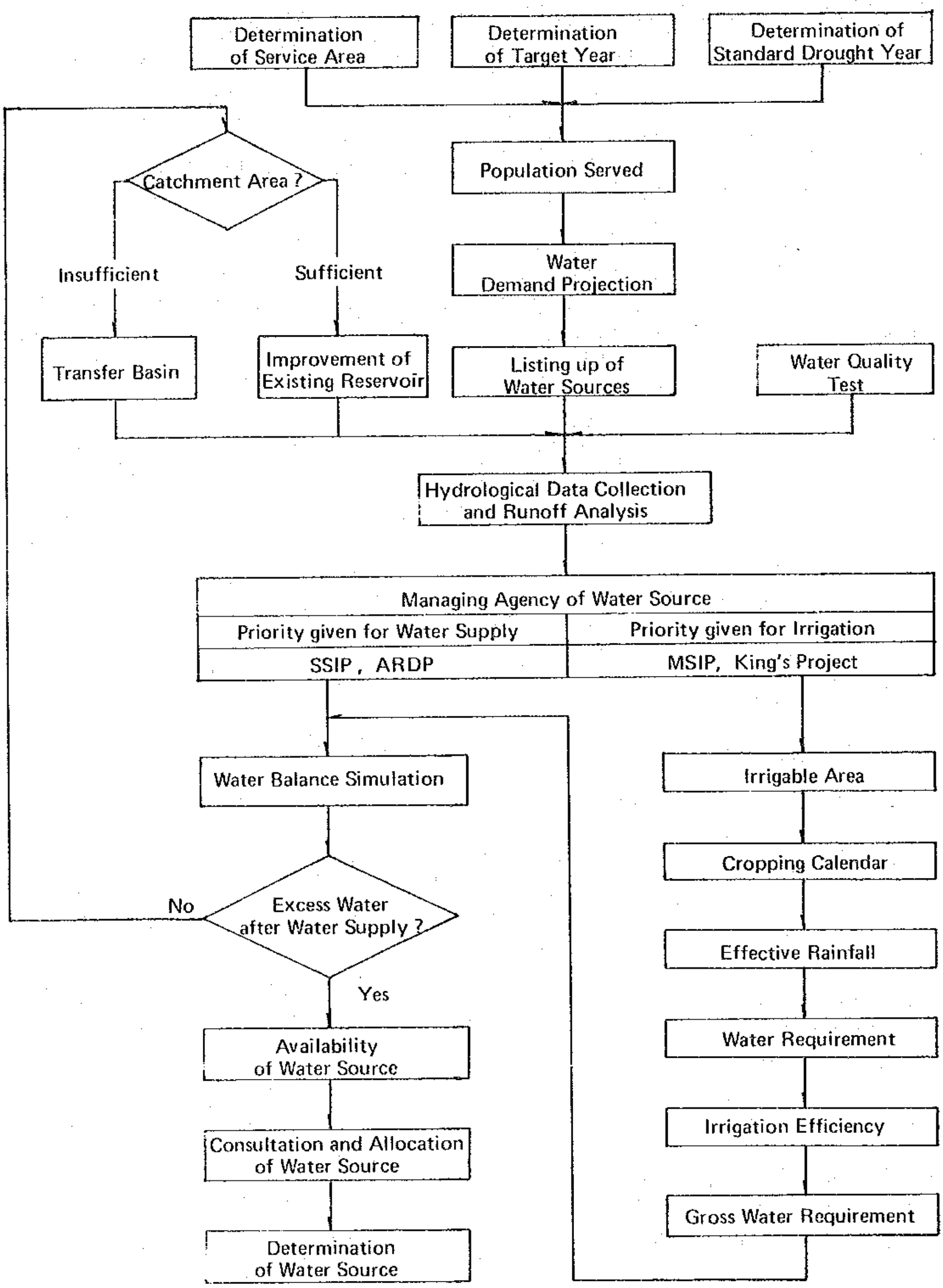
(11) Huai Kha Yung (NSD, No.20)

- The Huai Kha Yung, which is one of the major tributaries of the Mun river is flowing near the SD. The catchment area at the intake point is 3,344 sq.km. The width of the river is about 50 m and a fluctuation of water level at intake point is about 10 m between the dry and the rainy season.

- Drought discharge in the design drought year was computed by about 12 cu.m per second from observed discharge records.

- Conclusion: There is no remarkable problem on the quantity of water intake because diversion discharge for domestic water supply is quite small in amount as compared with river runoff discharge.

Figure 5–5–1 Flow Chart of Water Balance Simulation



CHAPTER VI. COMPARATIVE STUDY OF ALTERNATIVE PLAN

CHAPTER VI. COMPARATIVE STUDY OF ALTERNATIVE PLANS

6.1. General Descriptions

6.1.1. General

In order to determine the lowest cost of the waterworks system of the respective Sanitary Districts, a comprehensive study was conducted based on the data/information collected, detailed field survey and analysis, design criteria and the results of a series of discussion meetings with the Thai authorities concerned.

A proposal was made for the most suitable system from intake to distribution pipeline, through the transmission pipe, the treatment plant, and the clear water reservoir. This proposal was made after careful reviews and studies had been made on hydrology, meteorology, results of field survey, preliminary design, and an economic evaluation.

The basic concepts to specifing on alternative plan to the study are itemized as follows:

- The raw water conveyance from water source to treatment plant is made by a pumping method because the majority of Sanitary District areas are located at elevation higher than the high water level of the water sources at the intake point.

- The water treatment plant, as a rule, can be constructed on public land within the SD areas. In taking raw water quality into consideration the plant is planned as a chemical-coagulation and rapid sand filtration type for surface water, and aeration and rapid sand filtration type for groundwater.

- Water is distributed to the service areas by elevated tanks, of which height can ensure a minimum dynamic pressure at the connection to the service pipes.

- Where groundwater is available in the SD areas, the total, or a part of the required water quantity, can be supplied by several wells.

- In planning available alternatives, it must be considered that the capacity and the location of the surface water source have a significant affect on the construction cost and the operation and maintenance cost of the whole water works. Also the distribution system for groundwater, such as the number and height of the elevated tank have an influence on the construction cost.

6.1.2. Study Procedure

The procedures mentioned below, as a rule, are followed so as to make alternative studies.

- Necessary data and information on the water sources are collected from the agencies or the authorities concerned.
- Availability of the surface water sources is confirmed by the water balance simulation. The available safety yield for groundwater was also confirmed by pumping tests at the newly drilled wells and/or the existing wells.
- The construction of a new reservoirs in principle would be more economical, if the distance between the proposed SD areas and the existing reservoir, is more than 15 km.
- The preliminary design is made on the respective alternative plans.
- The construction cost and the operation/maintenance cost are estimated.
- The optimum plan is selected among the alternatives from the viewpoint of economy, in principle. If the costs of the alternatives are nearly equal, the optimum plan is selected from the technical point of view.
- The alternative study was made to confirm the least cost, and the comparison for the purpose was carried out by way that those present worth factors of the capital cost for initial two years of the construction period, and the operation and maintenance cost for 50 years of the project life, shall be discounted by 12 percent.

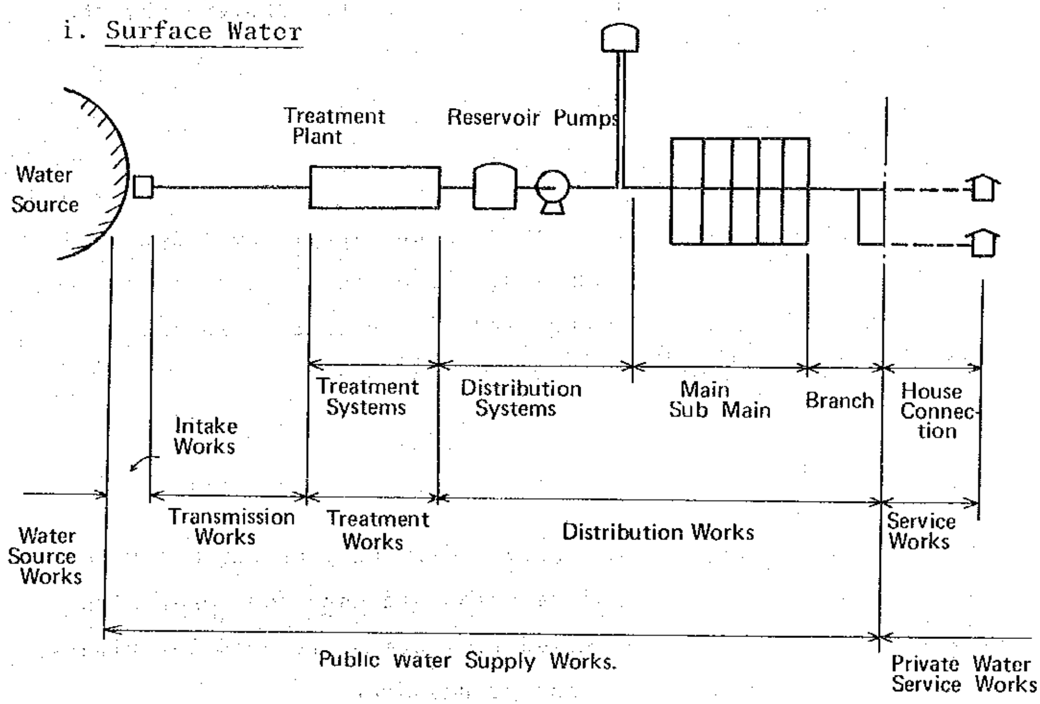
6.2. Design Criteria

6.2.1. Water Supply

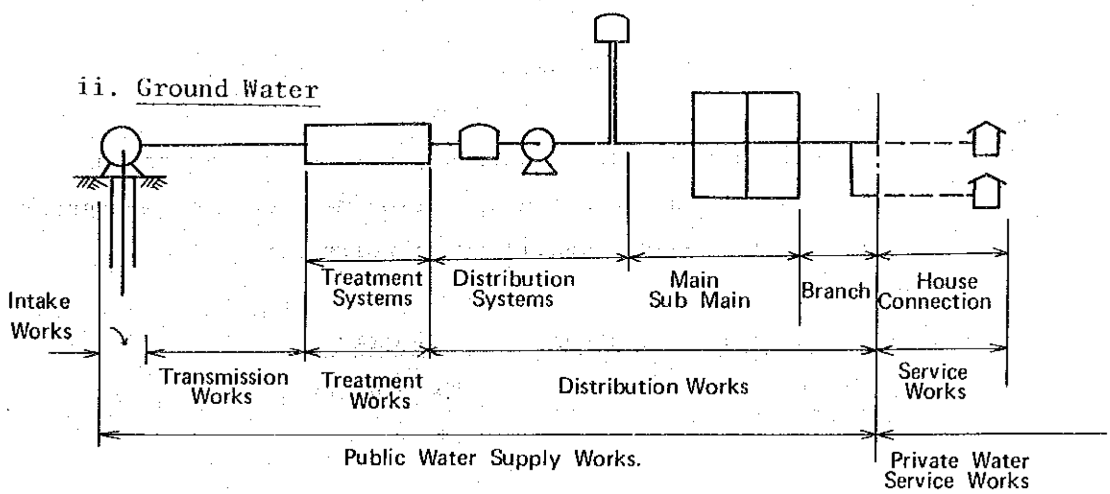
Basic arrangements of the waterworks is shown in Figure 6-2-1.

Figure 6-2-1 System Arrangement of Waterworks

i. Surface Water



ii. Ground Water



6.2.2. Intake Facilities

The water sources available in the NSDs and their surrounding areas are classified into three categories, reservoirs or ponds, rivers and groundwater. The intake method differs from one NSD to another depending on the water sources.

Since the SD areas are generally higher than the site of intake facilities in elevation, water should be mainly conveyed by the pump-pressuring method.

(1) Improvement of Reservoirs

The embankment of reservoirs or ponds should be heightened to the required level in accordance with the recommendation of water balance simulation when the capacity of the sources is not sufficient for new water supply.

(2) Intake Pump

The type of intake pump differs depending on the water sources. Generally, single suction volute pumps are used for reservoirs or ponds, vertical or inclined mixed flow pumps are used for rivers, and submerged pumps are used for groundwater.

(a) Number of pumps to be used

The following number of intake pumps is recommendable, taking into consideration operation/maintenance, emergency situations, and changeability of spare parts.

Water Source	Number	Remarks
Surface	2	One Standby
Groundwater	1	

(b) Design Capacity

The design capacity of the pump is 110 percent of the maximum daily water demand at the distribution reservoir in the treatment plant, taking into account additional water losses and the water used in the treatment plant.

6.2.3. Transmission Facilities

(1) Pipelines

It is preferable that the pipeline routes are as straight as possible, but as long as the pipe that is required does not increase greatly, it is recommendable to lay pipes along the existing roads, from a viewpoint of O & M and land acquisition.

(a) Hydraulic Design

(i) Standard Velocity

For economical design of transmission pipelines with pressurizing case, the detailed study on the cost evaluation between capital costs, O & M costs and diameters of pipes was presented in Appendix B. Standard design velocity is determined as follows;

Diameter (mm)	Velocity (m/s)
50 - 150	0.5 - 1.0
200 - 400	0.7 - 1.6

(ii) Hydraulic Formula

The Hazen William's formula is adopted here.

$$I = 10.666 \times C^{-1.85} \times D^{-4.87} \times Q^{1.85}$$

Where, I: Hydraulic gradient
C: Velocity coefficient
D: Diameter(m)
Q: Discharge (cu.m/sec)

C-value is selected from the following Table.

Kind of Pipe	C-value
Mortal lining pipe	130
Asbestos cement pipe	140
Polyviniyl chloride pipe	140

(b) Pipes

Asbestos pipes are mainly used in consideration of the diameters and costs. These pipes, however, are frial to impact, so that the pipes should be carefully transported, handled and installed under the road with an adequate earth cover. Steel pipes with casing are used for the railway or highway crossings.

The standard laying depth minimum is as follows:

Field .... 0.80 m
Under the road .... 1.0 m

(c) Others

Sluice valves, air valves and blow-off valves are installed for the purpose of safety maintenance of the pipelines.

(2) Open Canal

Open canals are planned as feeder canals for the purpose of supplemental water supply to the reservoirs or ponds.

The Manning's formula for friction losses is adopted.

$$Q = A \times V$$
$$V = \frac{1}{n} \times I^{1/2} \times R^{2/3}$$

Where,
Q: Discharge (m^3/s)
I: Hydraulic Gradient
A: Flow area (m^2)
V: Flow velocity (m/s)
R: Hydraulic means depth (m)
n: Coefficient of roughness

n-valve is selected from the following Table

Lining Condition	n-Valve
Earth canal	0.030
Reinforce concrete canal	0.015

6.2.4. Water Treatment Plant

(1) Selection of Water Treatment System

The most suitable treatment system for each of various water sources is selected according to the characteristic of the raw water. The treatment system suitable for various water quality is basically selected from the Table 6-2-1. And the water treatment systems are classified into the following Figure 6-2-2.

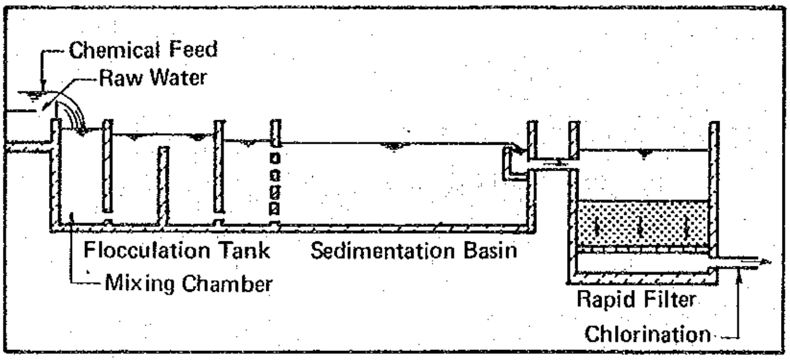
At treatment system suitable for the raw water of respective NSD waterworks can be selected from the water quality analysis as shown in Table 5-4-1 and 5-4-2, and the guideline as shown in Table 6-2-1.

Judging from the characteristic of the raw water of respective NSD waterworks, a rapid sand filtration can be applied to most of the NSD waterworks.

Since the characteristics of water quality is changeable depending on the environment of water source, meteorological condition and so on, regular water quality tests are required.

Therefore, it is recommendable to make a survey and test on the water quality at the detail design stage.

Figure 6-2-3. Rapid Sand Filtration System



(2) Design Criteria of Treatment Facilities

(a) Water flow measuring device

A measuring device of raw water flow, which is measured by a rectangular weir installed at the receiving well, is one of the most important devices for determining chemical dosing and operation/maintenance.

(b) Rapid Mixing Facilities

Rapid mixing is the process of immediately dispering the entire dose of chemicals throughout the raw water by agitating the water violently.

A hydraulic rapid mixing devices utilizing the difference of water head is adopted and used in combination with the measuring facilities.

(c) Coagulation and Flocculation Facilities

Flocculation is the process of gentle and continuous stirring of coagulated water for the purpose of forming colloidal particles called floc which can be readily removed by settling.

If a vertical type baffled channel flocculator is adopted, where the baffles can be adjusted to the change of water flow and water quality.

(d) Sedimentation

Sedimentation is the process of settling flocs aggregated by a flocculator by slow horizontal flow and removing the flocs sedimented on the bottom of the basin.

The basin consists of an inlet zone, a settling zone, an outlet zone, and a sludge zone.

Sludge is to be drained off regularly.

- ° Detention time .... 3 hours
- ° Flow velocity .... 0.1 m/min
- ° Turbidity of water in outlet zone..................... less than 15
- ° Number of basin .... 2 basins (more than $50m^3/h$) 1 basin (less than $40m^3/h$)

(e) Rapid Sand Filter

Filtration is the process of purifying the water by passing it through the sand.

Since the friction of filtered materials becomes bigger as time passes, the filtered materials are washed when the friction loss attains about 1.5 m head.

Mud balls and cracks in the surface of sand layer and augmented size of the sand should be removed by combined use of surface wash and back wash.

° Filtration rate .... 120 m/day
° Number of basin .... 2 basins (more than $50m^3/h$)
  1 basin (less than $40m^3/h$)
° Back wash velocity ..... 0.60 - 0.65 m/min
° Surface wash water ..... 0.15 - 0.20 m/min
° Surface wash pressure .. 1.5 kg/cm^2

(f) Chemical Dosing

The dosing method of aluminum sulfate is as follows;

(i) Alum solution (normally 5%) is prepared in special tanks with a holding capacity of 10 hours coagulant feeding requirements.

(ii) Two tank are required, one in operation, while the solution is being prepared in the other.

(iii) If the necessary alkalinity of the raw water as compared to the coagulant is insufficient, alkaline (soda ash) should be added to the water.

(g) Disinfection Facilities

Disinfection is the most important requirement of drinking water. Bleaching powder is dosed in the distribution water as a chemical disinfectant.

Pre-chlorination is required for the purpose of controlling algaecide.

(h) Aeration

Aeration is the process of bringing the raw water into intimate contact with air for the purpose of increasing the oxygen content. A multiple tray type is recommendable for ground water treatment in this project.

This type has three to nine trays on which 5 to 15 cm size stones or ceramic balls are put and brings the raw water into contact with air by the mechanical action of running water through serial of trays.

- Number of trays 5
- Space of trays .... 0.5 m
- Required area .... 6.0 m^2

6.2.5. Distribution System

Distribution system consists of a distribution reservoir, distribution pumps, an elevated tank and distribution pipelines.

(1) Water Supply Level

The connection level in the target year is to be at the house connection level in principle. According to topographical and socio-economical situation, however, the yard connection level or communal tap level can be considered.

(2) Design Discharge of the Pipeline

The design discharge is to be the hourly maximum water demand in an average water demand normal condition or the total of the daily maximum water demand and the necessary quantity of water for fire-fighting, whichever is bigger. The quantity of water for fire-fighting per one hydrant is as follows.

Population 10,000 ...... 0.50 m^3/min.
Population 10,000 ...... 0.26 m^3/min.

The maximum hourly water demand is compared with the total of the maximum daily water demand and the quantity of water for fire-fighting in the Table 6-2-2.

Table 6-2-2. The Comparative Table of Water Demand

NSD Code No.	Population	Population Served	M.D. W.D. (m^3/h)	Fire Fighting (m^3/h)	Total (m^3/h)	M.H. W.D. (m^3/h)
5	8,559	6,000	37.5	15.6	53.1	56.3
6	6,366	4,500	28.1	15.7	43.7	42.2
7	19,028	13,300	83.1	30.0	113.1	124.7
8	24,089	16,900	105.6	30.0	135.6	158.4
10	7,037	4,900	30.6	15.6	46.2	45.9
12	7,190	5,000	31.3	15.6	46.9	46.9
13	8,788	6,200	38.8	15.6	54.4	58.1
17	15,084	10,600	66.3	30.0	96.3	99.4
18	12,310	8,600	53.8	30.0	83.8	80.6
20	7,011	4,900	30.6	15.6	46.2	45.9

Remarks: M.D.W.D; Maximum daily water demand
M.H.W.D; Maximum hourly water demand

Therefore, the design quantity for pipeline is to be the hourly maximum water demand, since this level is greater of the two.

(3) Water Pressure

(i) The minimum dynamic water pressure is to be 1.0 kg/cm^2 at the house connection level. However, the minimum water pressure is allowed to be 0.7 kg/cm^2 at the yard connection level or communal tap level.

(ii) The maximum dynamic water pressure is to be 3.0 - 4.0 kg/cm^2.

(4) Distribution Facilities

The distribution reservoir is provided to balance the constant supply rate from the water source and treatment plant with the fluctuating water demand in the service area. The storage volume should be large enough to accommodate the cumulative difference between water supply and demand. The capacity of the distribution reservoir and elevated tank is estimated in Appendix B.

(a) Distribution Reservoir

The capacity of distribution reservoir is to be six hour's volume of the maximum daily water demand.

(b) Elevated Tank

A gravity flow method from the elevated tank is used for distribution. The capacity of the elevated tank is to be two hour's volume of the maximum daily water demand. The low water level of the tank is to be the level which can ensure the minimum water pressure at all the connections to the service pipes.

(c) Distribution Pumps

Three pumps are provided, and two pumps driven by electric motor and one driven by engine for standby. The capacity of the pumps is to be determined by the maximum hourly water demand. They are operated according to the water level in the elevated tank. The single suction volute pump will be adopted.

(d) Distribution Pipeline System

The network system is generally adopted. The network system is classified into the following parts.

Classification	Diameter (mm)	Pipe Material
Distribution Main	more than 100	Asbestos cement for more than 150 mm Polyvinyl Chloride for 100 mm
Distribution Sub-main	75	Polyvinyl Chloride
Distribution Branch	50	- " -
Service Pipe	10	- " -

The pipe materials are selected based on inner water pressure cost and actual results in the PWD's waterworks. (Appendix B)

Table 6-2-1 Selection of Water Treatment System

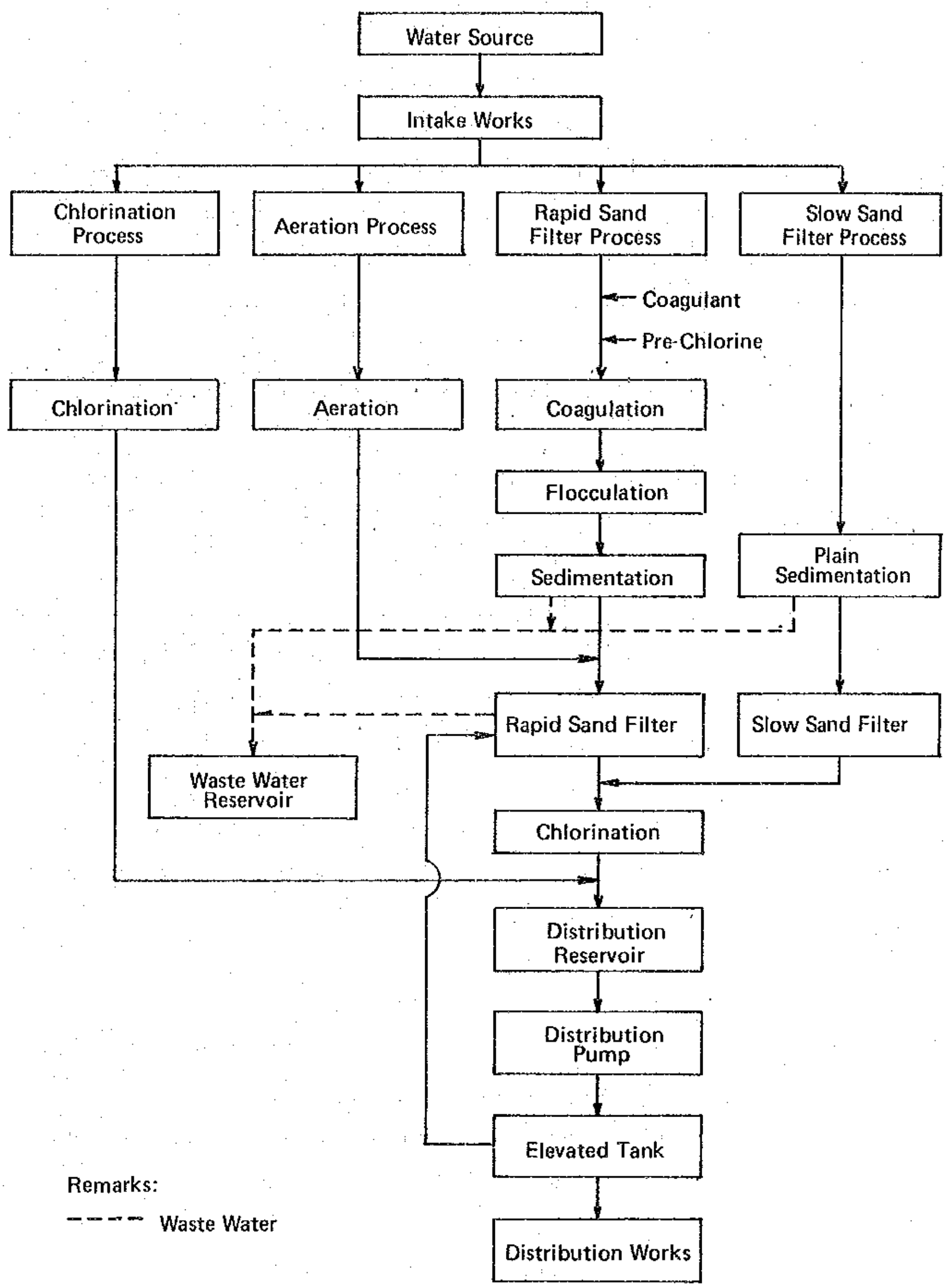
Water Source	Raw Water Quality (Maximum Annual) PH	Turb.	Color	Fe	Treatment Process
Groundwater (A)	6.5-8.5	< 5	< 5	< 1.0	Chlorination
Groundwater (B)	6.5-9.2	< 30	< 15	< 3.0	Aeration + Rapid Sand Filter
Surface Water (A)	6.5-9.2	< 15	< 15	< 1.0	Slow Sand Filter
Surface Water (B) & River	5.0-9.2	<1,000	< 30	< 5.0	Rapid Sand Filter

Note: 1) Table 6-2-1 is generally applied to select an adequate treatment process from water source to treatment plant, and the table are rather preliminary standard.
In case that the results of water quality analysis are nearly equal or over than the indicated figures, by carrying out analysis such as jar test, it is necessary to judge whether the water can be treated for drinkable or not, its treatment process is economical or not in respect to chemical dosage and O/M is possible or not.

2) Rapid sand filter process for groundwater requires pre-chlorination in some case or not require it in other case. Its selection depends on the raw water quality analysis and estimation of change of the water quality.

3) Selection of slow sand filtration process is based on the water quality analysis over a year in due consideration of contamination of the water.

Figure 6-2-2 Classification of Water Treatment System



6.3. Alternative Study of Waterworks

6.3.1. General Descriptions

As discussed in the previous section, the available water sources for the proposed Sanitary Districts only consisted of surface water, except the Sanitary Districts of Kusuman, Phon Charoen and Nong Song Hong where groundwater is useful as water sources for full and/or partial water requirements.

So the establishment of the possible source alternatives, for the respective Sanitary Districts, and their comprehensive evaluation were carried out, concentrating on the surface water sources in order to verify the lowest cost system.

Furthermore, since most of the SD service areas extend almost flat with little topographical fluctuation, there will be no cost difference among the alternatives for one SD. The comprehensive evaluation, therefore, mostly concentrated on the intake methods and the water conveyance routes for a new system, as well as the construction costs and O.M costs for available water source alternatives, which were recommended in the water balance simulation from viewpoint of water quality and quantity.

On the other hand, for the three NSD areas where the groundwater is available, a comparative study was carried out on a distribution system with groundwater pumping facilities and on the overall construction cost and operation/maintenance cost using either surface water or the groundwater as sources.

6.3.2. Basic Technical Concept of the Alternative Plans

Location:

The nearest water source from the SD area is favourable to construction cost and O/M cost in general terms.

Utilization of Existing Reservoirs and Ponds

The existing reservoirs or ponds that are used for irrigation or domestic water at present will be utilized to minimize construction cost of the project, if there are no problems in supply capacity, water right and O/M by the agency concerned.

The reservoirs, which were constructed under SSIP by RID to store water, are usually made with an embankment near natural depressions or rivers, and have 4 to 5 meter dikes. In the cases where there is a shortage in capacity, some improvement works will be required.

There are two possible improvement methods, such as excavation of the reservoir bed or heightening of the dam embankment. The excavation method does not required the reconstruction of a spillway and intake structures. This, however, may involve some disadvantage in excessive sedimentation and salinity deposit.

On the other hand, the latter case will require heightening of dam top as well as improvement of the spillway and intake structures.

Construction of New Reservoir

In case that there are no existing reservoirs near the SD areas or where there is a need of long distance transmission pipeline works between the existing reservoir and the proposed treatment plant, a new reservoir around the SD shall be comparatively considered.

According to the preliminary study on the transmission pipeline for small scale waterworks, when the distance between the existing reservoir and the relevant SD area is more than 15 km, construction of a new reservoir is recommended because of the advantages in lowering the cost of construction and future operation/maintenance, and the case in maintenance services for facilities.

Water Transmission

Water transmission will be made by pipeline systems to prevent contamination of foul water or soil. In case that the water source is topographically low, the raw water shall be conveyed by using pumps.

The alignment of the transmission pipeline shall be selected in determining the shortest distance, or within public land along the public road since there will be the additional burden of land acquisition cost and construction of work roads or maintenance roads.

When the straightest distance between the existing reservoir and the SD area is less than 50 percent of the total length of the alignment along the public road, the straight alignment shall be selected together with an operation/maintenance road of 3.50 m in width.

Evaluation Method of Alternative Plan

A comparison of the respective alternative plans shall be made on the basis of the most economical method, in regard to the cost of construction and operation/maintenance.

The economic evaluation will be made on the basis of present worth value which can be computed from the capital cost for two-year construction period and the annual operation/maintenance cost during the project life of about 50 years with a discount rate of 12 percent.

6.3.3. Selective Comparison of Alternatives

A selective comparison and evaluation for the respective Sanitary District alternative plans was carried out based on the concepts, and the results of the survey and analysis. There are many possible alternative plans and a detailed study and evaluation are described in Appendix B of the report. The available alternative plans for cost comparison are summarized in Table 6-3-1.

(1) Kham Sakae Sang (NSD. No.5)

- Alternatives:
  Two alternative plans, such as the rehabilitation of Bun Chiwuk reservoir (Case-1) and the construction of a new reservoir (Case-2) were selected from the original four plans to evaluate the economic feasibility.

- Facilities dimension:

Item	Case-1	Case-2
Intake weir	1.0 LS	1.0 LS
Feeder canal	2,000 m	-
Transmission pipe (150 m/m)	5,800 m	500 m
Fill dam	-	1.0 LS
Motor output	7.5 KW	3.7 KW

- Capital and O/M cost:

Unit: ฿1,000

Item	Case-1	Case-2
Intake, feeder canal	600	100
Transmission pipe	1,450	130
Fill dam (New reservoir)	-	7,300
Sub-total	2,050 (1,940)	7,530 (7,130)
Electric charge	107 (890)	53 (440)
Total	(2,830)	(7,570)

Note: The figures in parenthesis indicate the present worth value after discounted with 12 percent rate.

- Conclusion:
  Case-1, with the rehabilitation of Bun Chiwuk reservoir, diversion weir, and feeder canal, was proposed as the optimum plan from the economic and technical points of view.

(2) Nong Bua Lai (NSD, No.6)

- Alternatives:
  The Nong Samp reservoir, which is situated near the SD area, is utilized for domestic water at present, and the reservoir has enough reserve capacity for water for a new waterworks by obtaining supplemental water from the Phai Lung reservoir during the dry period.

- Conclusion:
  There are no potential water resources other than the Nong Samp reservoir, from technical and economical points of view.

(3) Huai Thalaeng (NSD. No.7)

- Alternatives:
  There are two alternative plans to utilize the existing reservoirs such as the Nong Takai with a storage capacity of only 0.16 MCM (Case-1), and the Lam Chawuk with a capacity 22.2 MCM (Case-2). The former storage capacity of the former is less than the water demand in this area. Consequently, it is impossible to use the reservoir without heightening the dam embankment.

- Facilities dimension:

Item	Case-1	Case-2
Transmission pipe (200 m/m)	6,000 m	20,000 m
Dam top heightening	1.50 m	-
Motor output	30 KW	50 KW

- Capital and O/M cost:

Unit: ฿1,000

Item	Case-1	Case-2
Transmission Pipe	2,400	8,100
Dam top heightening	5,400	-
Sub-total	7,800 (7,400)	8,100 (7,700)
Electric charge	428 (3,600)	785 (6,500)
Total	(11,000)	(14,600)

Note: The cost of intake pumping plant was excluded from the above table because these costs are almost same.

- Conclusion:
  Utilization of existing Nong Takai reservoir with some improvement works is recommendable for stable water supply because the operation/maintenance cost for the proposal accounts for about 50 percent of alternative one.

(4) Nong Ki (NSD, No.8)

- Alternatives:
  Available water sources in and around the Sanitary District area are only the Tung Kraten reservoir, which has the storage capacity of 1.60 MCM. The reservoir was constructed for the multipurpose use under the ARD's accelerated rural development project.

- Conclusion:
  The Tung Kraten reservoir is only the water source for the project and no other alternative plan can be considered.

(5) Huai Rat (NSD, No.10)

- Alternatives:
  Huai Talet reservoir, with capacity of 18.5 MCM is located at 15 km southwest of the SD area. There are two routes of the main irrigation canal from this reservoir. Rehabilitation works of the canal will be completed by 1987 under the NESSI Project of RID. There are no available alternative water source other than that mentioned above. The project will be expected to use the right main irrigation canal as for water transmission, and a link, canal shall be constructed for the additional 100 m, up to water treatment plant.

- Conclusion:
  Utilization of Huai Talet reservoir and the right main irrigation canal is the optimum plan for the subject Sanitary District waterworks. In connection with the above, a small scale regulating pond is required to supplement the water in case of an interruption in irrigation water supply due to periodical canal rehabilitation works. Fortunately, an existing pond, which has the sufficient capacity of 30,000 cu.m (45 day's water demand), is situated near the proposed water treatment plant.

(6) Khun Han (NSD. No.12)

- Alternatives:
  Special attention must be paid to the phasing plan of the waterworks system development. Recently, the Sanitary

District boundary was expanded from the original area of 2.2 sq.km to 12.0 sq.km. Most of the newly expanded area, however, is a thinly populated agricultural zone.

The subject project can be phased into the first phase for the original and the second phase for a new area. There is only one water source, being the Nong Si reservoir, with capacity of 3.8 MCM in the SD area, and the Nong Si river is connected to the outlet of the reservoir. Three possible alternative plans were prepared in view of the intake method of water from the water source.

- Conclusion:
  The method of diversion of water from the water source was concluded to be only available through the Nong Si river because the Royal Irrigation Department (RID), who manages the said reservoir, could not give a consent to a direct diversion of water from the reservoir.

(7) Kusuman (NSD, No.13)

- Alternative:
  Four available alternative plans were proposed, in which two plans were based on a surface water source and the other two were based on a groundwater source. With regard to the surface water source, the utilization of the existing Huai Daeng Reservoir, and the construction of a new reservoir near the SD on the Huai Saphoe which has 20 sq.km catchment area with an annual runoff at least 2.0 MCM, were proposed. On the other hand, a groundwater source is also available to meet the subject SD water demand which was evaluated in the previous Chapter V of this report. From the evaluation of safety yield, three deep wells would be necessary to supply raw water to the entire subject area. The two proposed plans for the deep wells or groundwater source, is to evaluate which method of the treatment is more efficient. The single point pressuring method, which is one treatment plant or the multi-point pressuring method, which would be a treatment plant for each well, would be the most feasible from the technological and operation/maintenance viewpoints.

- Capital and O/M cost:
  It is clear that a new reservoir construction cost is much higher than the utilization of the existing Huai Daeng reservoir. Furthermore, the detailed cost comparison of both the facilities of the surface and groundwater sources is shown in Table 6-3-2.

- Conclusion:
  Three deep wells with single pressuring method are recommended as the optimum waterworks system in view of economy, water quality and quantity.

(8) Phon Charoen (NSD. No.17)

- Alternatives:
  Available alternative plans were considered to be similar to the Kusuman. Nong Loeng Reservoir, for with capacity of 2.0 MCM, will be used as the water source for (Case-1). Another alternative, in the surface water category, is the construction of new reservoir (Case-2). For the groundwater source four deep wells with a safety yield of 7.0 cu.m per hour can be drilled in and around the SD area judging from the hydroelectric prospecting and pumping test.

- Facilities dimension for surface water source:

Item	Case-1	Case-2
Transmission pipe (200 m/m)	12,500 m	1,300 m
Reservoir	-	370mx370mx4.5m
Motor output	22 KW	11 KW

- Capital and O/M cost:

Unit: ฿1,000

Item	Case-1	Case-2
Transmission pipe	5,500	520
Reservoir	-	11,000
Sub-total	5,500	11,520
	(5,200)	(10,900)
Electric charge	428	157
	(3,600)	(1,300)
Total	(8,800)	(12,200)

As shown in Table 6-3-2, the combined use of Nong Loeng reservoir and deep wells and/or simple water source will result in almost the same cost when the capital and O/M costs are considered.

- Conclusion:
  The single water source by utilization of the existing Nong Loeng Reservoir is recommended from the simple operation and maintenance aspect.

(9) Nong Song Hong (NSD, No.18)

- Alternatives:
  The three alternative plans for the subject area waterworks are the utilization of the existing Nong Song Hong Reservoir (Case-1), the utilization of the Nong Kom Ko Lake (Case-2), and a combination of a surface water and groundwater source.

  The Nong Song Hong Reservoir with the capacity of 0.38 MCM, would require the heightening of its dam top to increase the storage capacity to meet the water demand which could include an irrigation requirement. Four deep wells could be dug within the SD area as supplemental water sources to the surface water. The safety yields of the proposed deep wells would be about 7.50 cu.m per hour, as was determined from the results of drilled well pumping test.

- Facilities dimension:

Item	Case-1	Case-2
Transmission pipe	200 m	8,500 m
Dam embankment	1.30 m	-
Motor output	3.7 KW	11.0 KW

- Capital and O/M cost:

Unit: ฿1,000

Item	Case-1	Case-2
Transmission	50	3,500
Dam embankment	4,050	-
Sub-total	4,100 (3,880)	3,500 (3,300)
Electric charge	53 (440)	157 (1,300)
Total	(4,320)	(4,600)

A cost comparison on the single and/or combined water sources was tabulated in Table 6-3-2.

- Conclusion:

  A single water source, using the existing Nong Song Hong reservoir, is the most suitable source, rather than the combined water source system, from the economic and operational points of view.

(10) Huai Kya Yung (NSD, No.20)

- Alternative:

  There is no reservoir in this area other than the Huai Kya Yung, which runs from south to west along the borderline of the SD. It flows to north, with discharge of 11.7 cu.m per second, during the dry season.

  The location of pumping station along the Huai Kya Yung shall be designed in taking into account the fluctuation of the water surface in the river, which is approximately 10 meter in difference, the velocity of flood, the deposit of soil near the proposed pumping station, and rock excavation for the facilities.

  A alternative plans were prepared only for the intake method of water from the river being the selection of the most suitable pump types. The pumps that are viable choices are inclined shaft, vertical shaft, and horizontal shaft pumps.

- Conclusion:

  The inclined shaft pump is comprehensively superior to the other alternatives from technical, operational and structural suitability.

Table 6-3-1 The Comparative Table of Available Alternative Plans

Code No.	M.D.W.D. (m^3/d)	M.H.W.D. (m^3/h)	A.A.W.D. (m^3/y)	Case	Length of Transmission (m)	Water Source available	Capacity (m^3)	Capable Methods
5	990	38	300,000	1	5,800	Bung Chi Wuk Reservoir	340,000	
				2	500	New Reservoir	300,000	New Reservoir Construction
6	740	28	200,000	1	0	Nong Sang Reservoir	300,000	
				2	0	New Reservoir	200,000	New Reservoir Construction
7	2,200	83	640,000	1	6,000	Nong Takai Reservoir	160,000	Heighting of Embankment
				2	20,000	Lam Chamuk Reservoir	640,000	New Reservoir Construction
8	2,790	105	810,000	1	3,050	Toung Ka Ten Reservoir	1,600,000	
				2	-	-	-	
10	810	31	240,000	1	600	Huai Kadong River	-	
				2	100	Huai Talet Reservoir	18,500,000	
12	830	31	220,000	1	120	Nong Si Reservoir	3,800,000	
				2	500	Nong Si River	-	
13	1,020	39	300,000	1	4,250	Huai Daeng Reservoir	1,200,000	
				2	1,690	Deep Well	$18m^3/h \times 3$	Single Point Pressurizing Method
				3	0	"	"	Multi Points Pressurizing Method
17	1,750	66	510,000	1	12,500	Nong Loeng Reservoir	2,000,000	
				2	12,500 5,070	Nong Loeng Reservoir Deep Well	2,000,000 $7.0m^3/h \times 4$	Single Point Pressurizing Method
				3	12,500 0	Nong Loeng Reservoir Deep Well	2,000,000 $7.0m^3/h \times 4$	Multi Points Pressurizing Method
18	1,420	53	420,000	1	200	Nong Song Hong Reservoir	400,000	
				2	200 2,700	Nong Song Hong Reservoir Deep Well	400,000 $7.5m^3/h \times 3$	Single Point Pressurizing Method
				3	200 0	Nong Song Hong Reservoir Deep Well	400,000 $7.5m^3/h \times 3$	Multi Points Pressurizing Method
				4	200 0	Nong Song Hong Reservoir Deep Well	400,000 $7.5m^3/h \times 3$	2 Pipeline Networks
20	810	31	240,000	1	1,000	Huai Kya Yung River	870,000 m^3/min	Inclined Shaft Pump
				2	1,000	"	870,000 m^3/min	Vertical Shaft Pump